TECH BRIEFS

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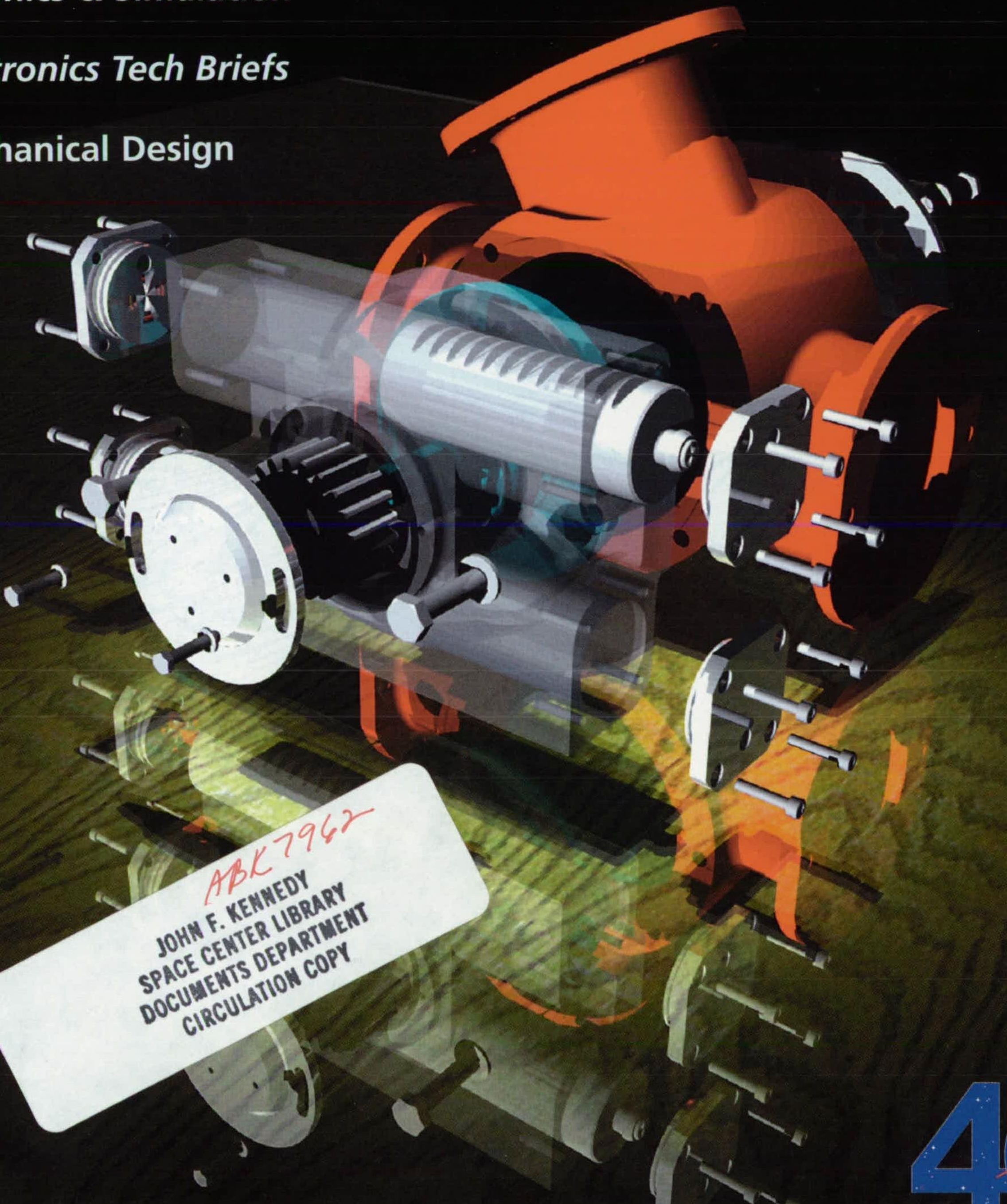
Special Section:
The Technology of Space Station

Graphics & Simulation

Electronics Tech Briefs

Mechanical Design



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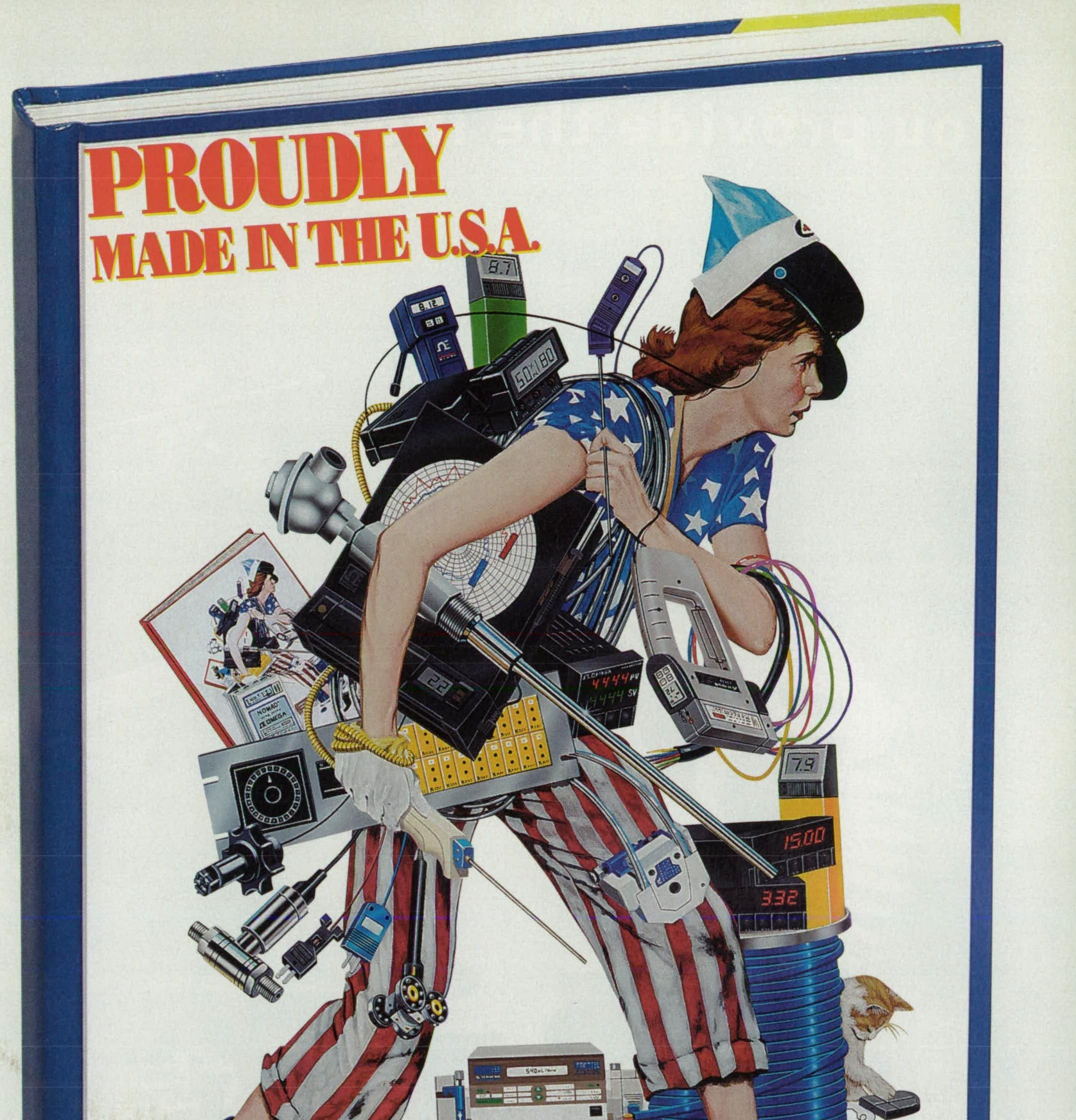
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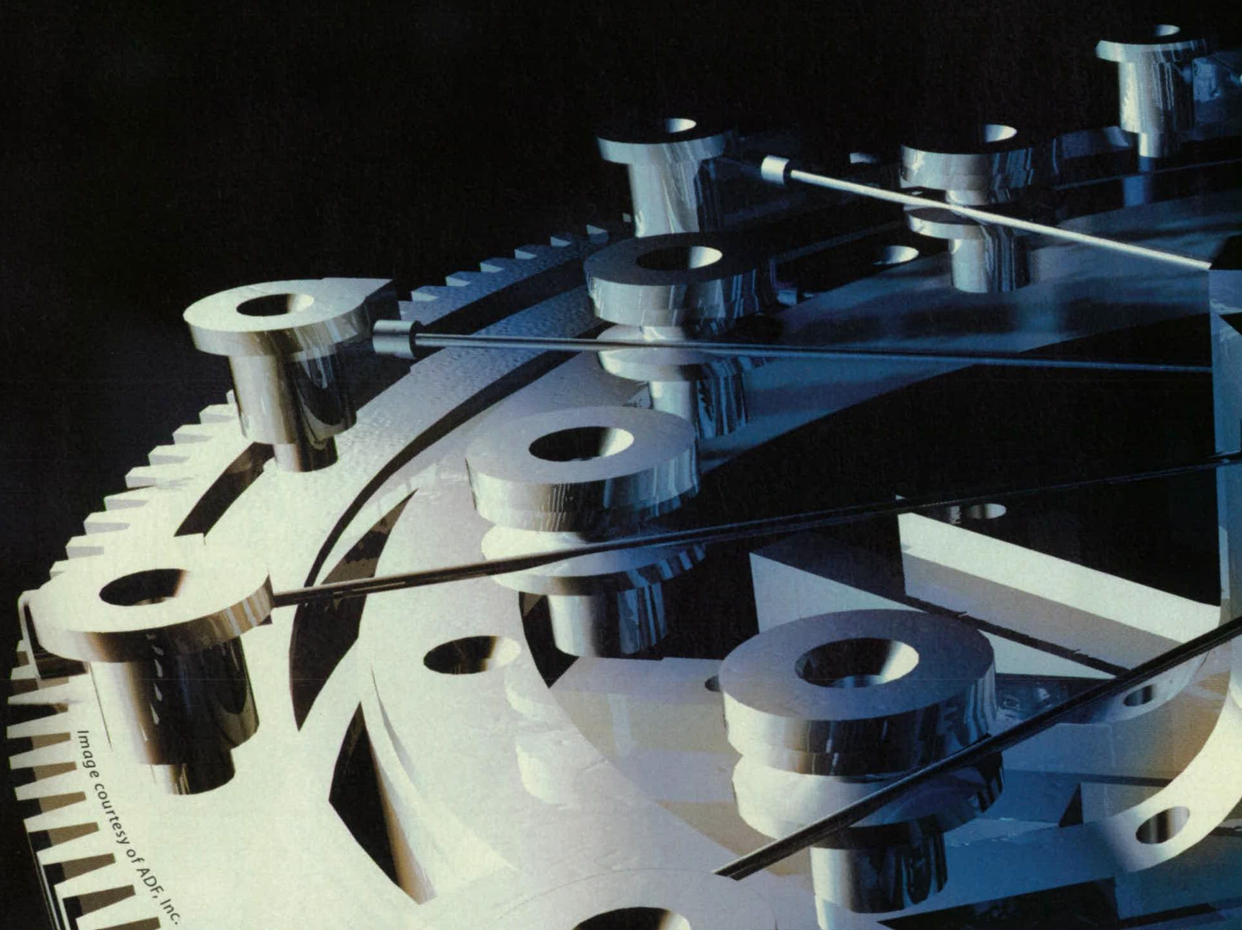

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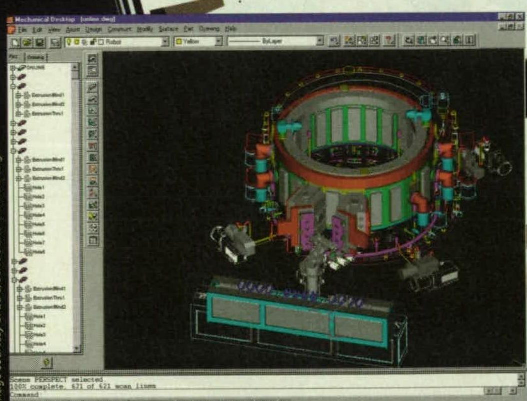

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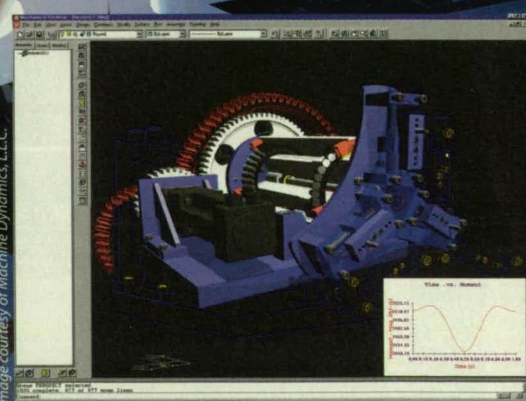

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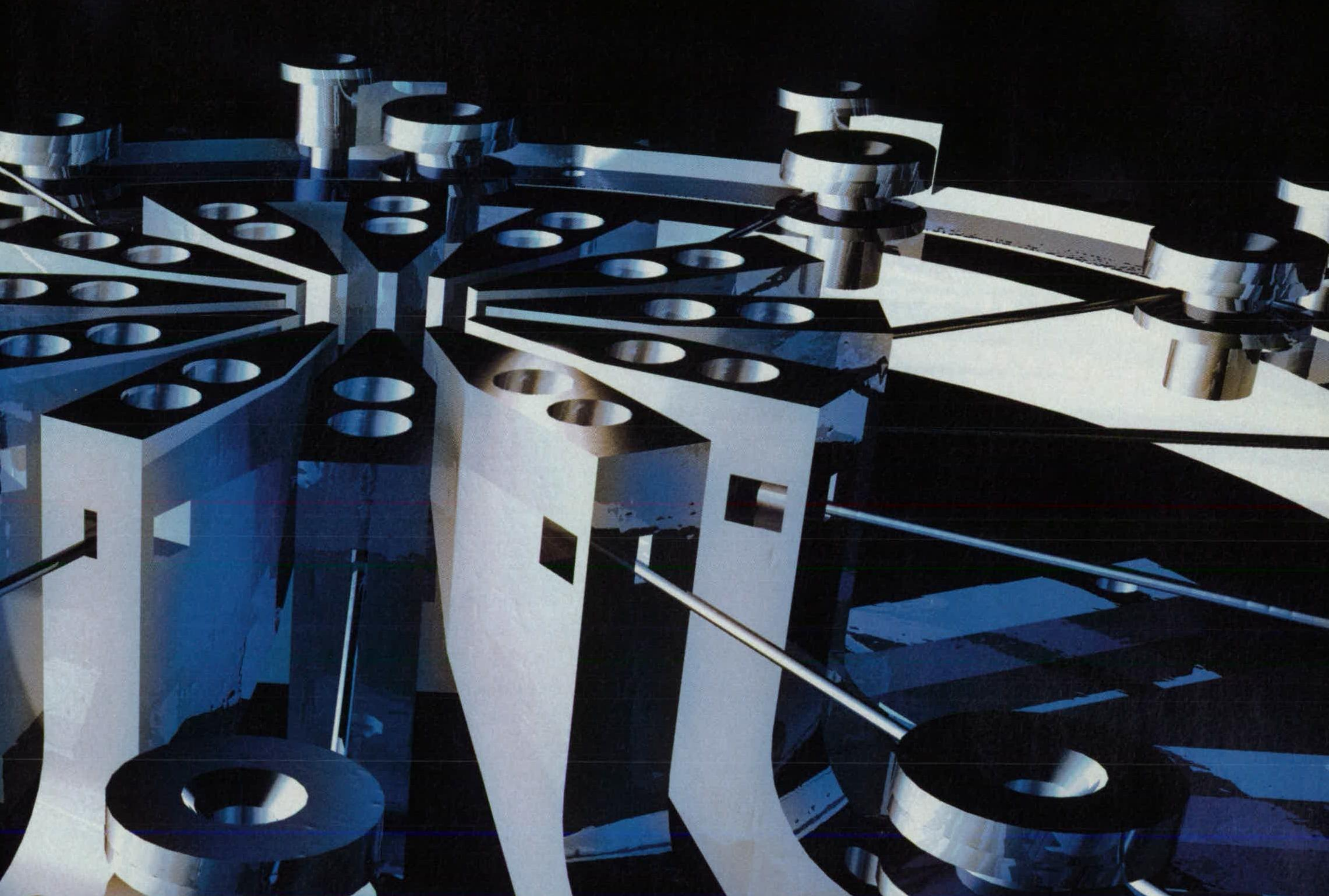

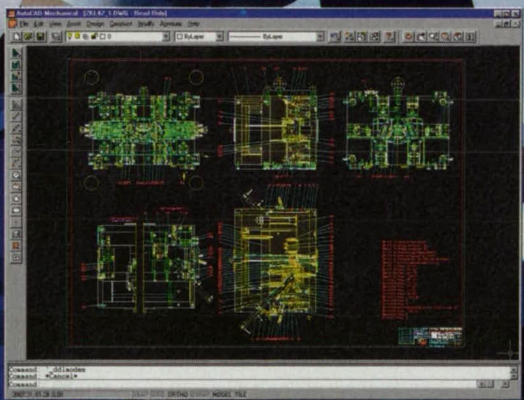

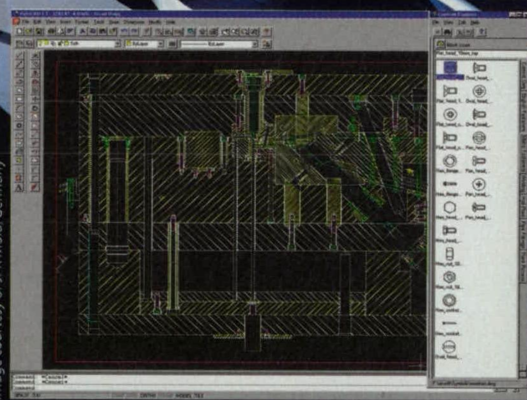

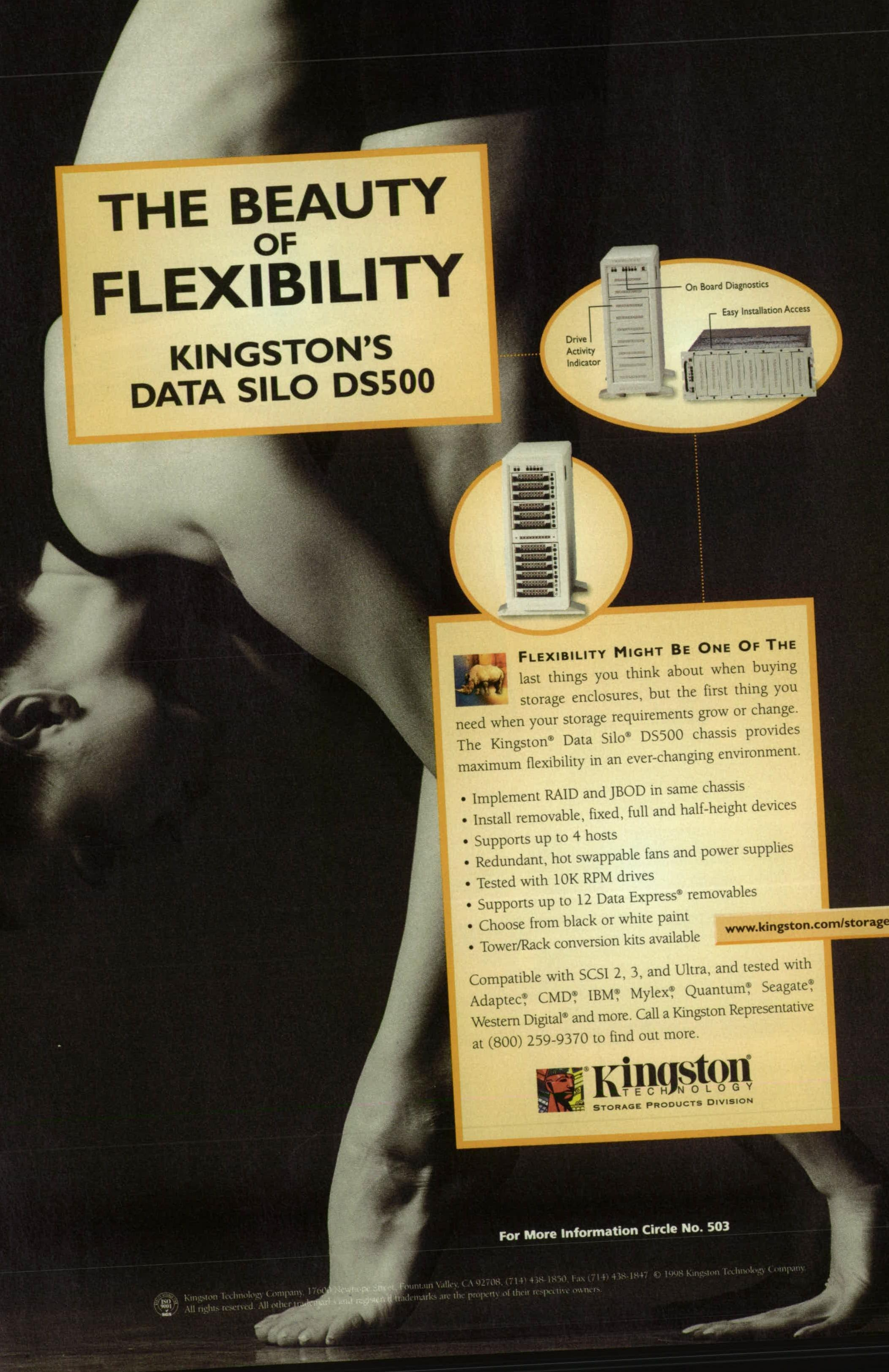
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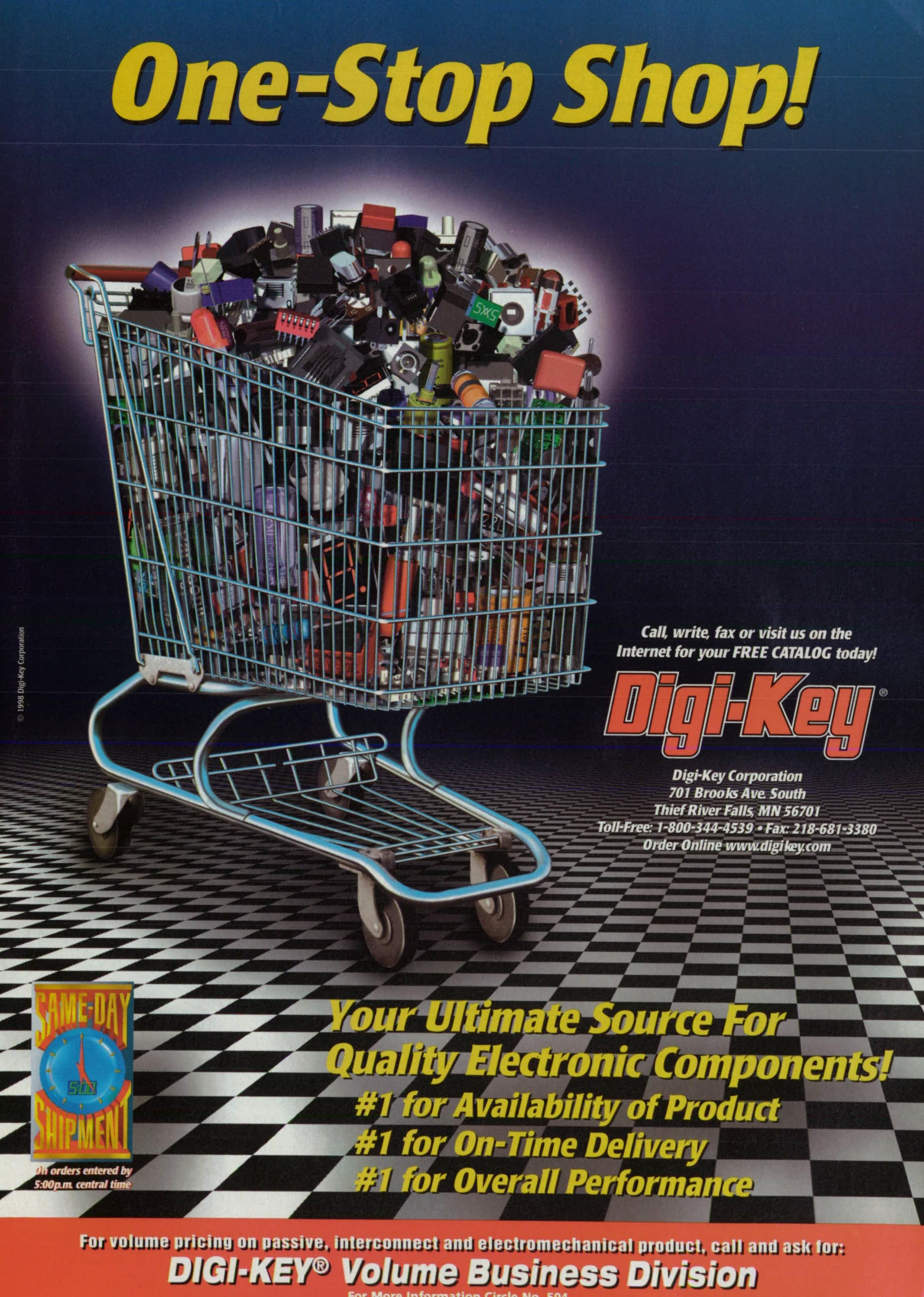
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NASA TECH BRIEFS

July 1998 • Vol. 22 No. 7

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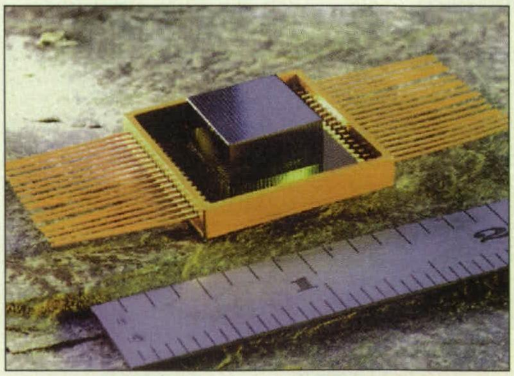

This month, we begin the second half of our year-long celebration of NASA's 40th anniversary with innovations in the areas of Electronics, Sensors & Robotics. The Memory Short Stack™ is an innovation developed by Irvine Sensors Corp. under a NASA contract. The 3D semiconductor package is a cube consisting of dozens of circuits stacked on top of each other. Today, the short stacks are used in virtually all types of electronic assemblies. For more information on this and other NASA-developed technologies, see the feature beginning on page 20.


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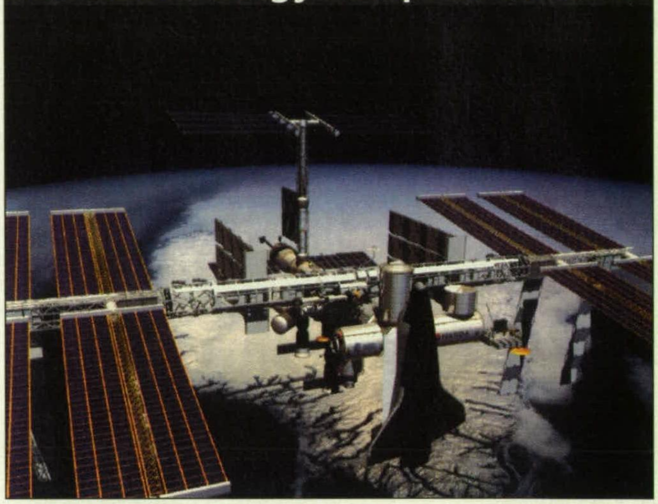
On the cover:
IPA 4.0 three-dimensional, photorealistic animation and visualization software from Immersive Design of Acton, MA, was used to produce this frame of an assembly simulation of a grain valve. In addition to IPA 4.0, this month's Special Coverage on Graphics & Simulation highlights other new software, as well as new NASA technologies in navigation simulation and graphical analysis of processes and effects. Our coverage begins on page 32.

(Image courtesy of Immersive Design)

The Technology of Space Station



79-96 *This year, the first component of the International Space Station (ISS) will be launched, more than three decades after NASA first envisioned the orbiting research facility. The ISS is becoming a reality thanks to 17 partner nations and hundreds of commercial suppliers. This special section looks at how the ISS came to be, focusing on companies that supplied their products to the design and construction of the station, and the breakthrough technologies that already have come from — and are expected to be discovered through — space station research.*

Special Supplement

1a-14a
Electronics Tech Briefs

Follows page 64 in selected editions only.

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Selected technological strengths: Fluid Dynamics; Life Sciences; Earth and Atmospheric Sciences; Information, Communications, and Intelligent Systems; Human Factors.
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Dryden Flight Research Center
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Goddard Space Flight Center
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Jet Propulsion Laboratory
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Langley Research Center
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Lewis Research Center
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Marshall Space Flight Center
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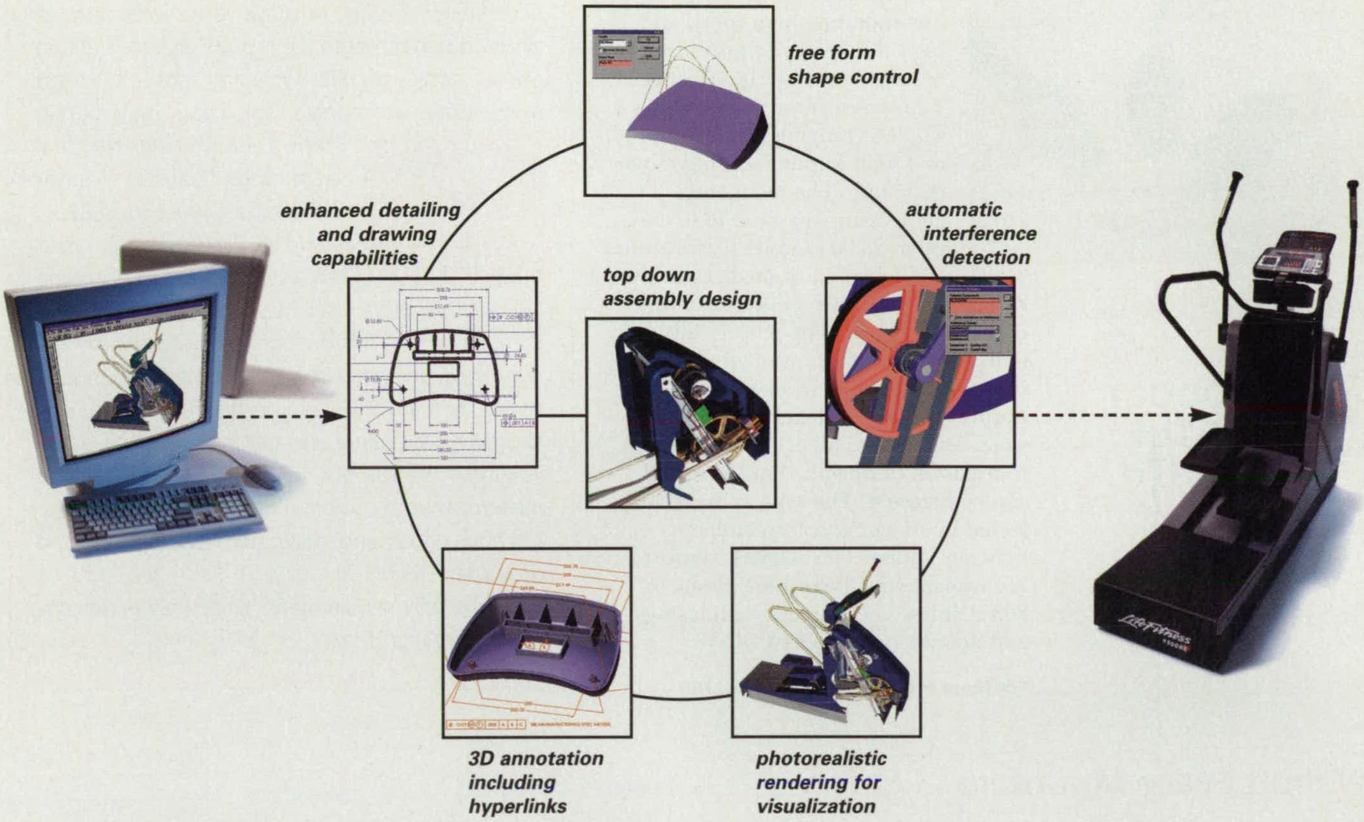

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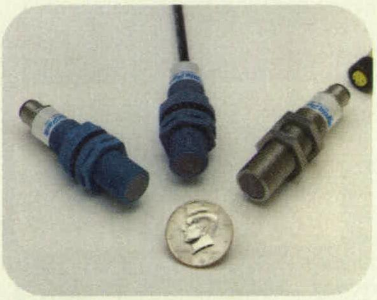

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We've listened to your requests to make the on-line TSP section more user-friendly. Now, instead of completing an information form for each TSP requested, you need only fill out the form once to access as many TSPs as you need. And, you can choose a user name and password so that when you leave the TSP site, you need only type in that name/password combination to access more TSPs. It's now easier and faster to view, search, and download Technical Support Packages, with a one-time-only requirement to complete the on-line information form.

Climb Every Mountain ... Safely

In May 1996, eight climbers died in their attempt to scale Mt. Everest. This year, NASA and Yale University are using advanced telemedicine technology to reduce the risk to climbers and possibly prevent or reduce casualties. In May, four members of the American Everest Expedition — Wally Berg, Eric Simonson, Greg Wilson, and Charles Corfield — were equipped with vital-sign sensors and wireless transmitters for their climb up the south side of Mt. Everest. Their vital signs — including heart rate, skin temperature, core temperature, and blood oxygen level — were to be transmitted back to a base camp set up at 17,500 feet, manned by a team of Department of Defense and Massachusetts Institute of Technology (MIT) personnel. The team was to collect and analyze the data on climber performance, endurance, physiologic status, and the effects of extreme exertion, hypoxia, and cold. Whenever possible, medical personnel also would receive video images of the climbers' progress.

NASA and Yale have been working in partnership since July 1997 to develop and test next-generation technologies, with the goal of finding new commercial applications for telemedicine. The Mt. Everest tests may lead to improvements in future automated medical-monitoring and medical-care systems for astronauts spending several months in space. The challenges faced by the Mt. Everest climbers — including adapting to high altitude and physiological stress — are similar to conditions encountered by astronauts.

NASA Administrator Daniel Goldin explained how this technology can help astronauts on the International Space Station. "To ensure a safe trip for our astronauts, we need the best computational, communication, engineering, and medical technology. At NASA, we are working on virtual environments for surgery, decision-support systems, and the most advanced medical-monitoring techniques. Just think what this could mean for health care here on Earth," said Goldin. "The NASA-Yale project is helping us achieve these goals. I wish our Mt. Everest pioneers great success as they help NASA climb the final frontier."

Reader Forum

Reader Forum is devoted to the thoughts, concerns, questions, and comments of our readers. If you have a comment, a question regarding a specific technical problem, or an answer to a question that appeared in a recent issue, send your letter to the address below.

I am thoroughly enjoying your series on 40 Years of NASA Innovations. Unfortunately, there will be many that are not covered. Back in the 1960s, for example, I did LOX cleaning of pressure transducers by flushing the unit with a cleaning fluid into a filter paper and inspecting it with a black light. That filter paper later was used in drip coffee makers. I also worked on mass spectrometers for deep space probes that later were used as breath analyzers for monitoring astronauts' health; as part of a Mars soil sample experiment; and as blood/gas analyzers in hospital intensive care wards. These are just two more of the NASA innovations that spun off into commercial applications.

John Mathis
Boeing - Rocketdyne Div.
Canoga Park, CA

As a special effects technician for film, television, and entertainment, I am constantly in need of motion control, photosensing, pneumatic, lighting, fiber-optic, electronic, and electrical parts, supplies, and materials. There seems to be a wealth of this information in NASA Tech Briefs. *Thanks!*

Brian Remaley
Remaley F/X
Glendale, CA

(From our On-line Reader Forum:)

We have an application in which we must use a sensor that has a power connector soldered to a penetration panel on the sensor. The connector is tin-plated steel with nickel alloy and tin-plated contacts (part number PTIH-8-4P). The application is on a GPS satellite with a 15-year mission. We can find a replacement connector with gold contacts, but we seem to be stuck with the fused tin-plated shell over copper to allow soldering to the panel. The mate will have gold contacts with electroless nickel shell. Will I have a problem connecting electroless to tin plating? Are there any other options? Any suggestions would be appreciated.

Jim Payne
Sandia National Labs
505-844-3336

Post your letters to **Reader Forum** on-line at: **www.nasatech.com** or send to: Editor, *NASA Tech Briefs*, 317 Madison Ave., New York, NY 10017; Fax: 212-986-7864.
Please include your name, company (if applicable), address, and phone number or e-mail address.

This month, in our year-long celebration of NASA's 40th Anniversary, we take a look at successful spinoff products and new applications of NASA technologies in the areas of Electronics, Sensors, and Robotics.

1980s

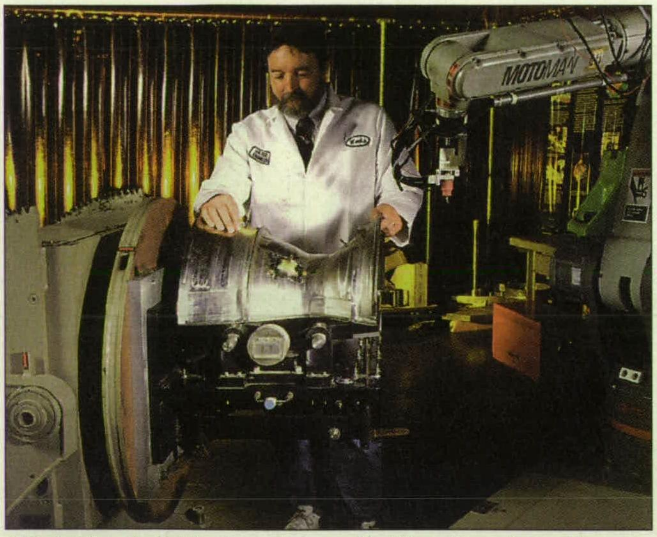
Grasping an Idea

End effectors are devices attached to the end of a robot arm for picking up, grasping, manipulating, and transferring objects. One manufacturer of these end effectors, Robotics and Automation Corp. of Minneapolis, MN, also makes the Automatic Robotics Tool-change System (ARTS) designed for the growing demand for multiple-task work cells for welding and plasma spray functions. Such functions require grinding and finishing; deburring, deflashing, routing, hole-drilling, or parts replacement; and multiple tool disk operations.

The technology in the ARTS system was developed originally under contracts with NASA's Marshall Space Flight Center and Rockwell International, a NASA contractor. The systems were designed to work with the company's Constant/controlled Force Device (CFD) series of end effectors and bench-mounted devices for controlling constant pressure of abrasive tools used to deburr, grind, polish, and finish products made by welding, molding, forging, casting, and machining.

The CFD line includes three end-of-arm devices and two bench-mounted devices, none of which require that the robot apply and control the force, only that it move along a programmed path over the work piece. The CFD applies and maintains the processing pressure of the finishing media to the work piece.

The ARTS-I is being used in industrial systems with six tool positions ranging from coarse sanding disks and abrasive wheels to cloth polishing wheels with motors. ARTS-II allows a robot to change welding torches automatically, or exchange a welding torch for a CFD end effector. More than 90 robotic work cells have been sold by Robotics and Automation using the CFD/ARTS devices.



A Rocketdyne technician inspects Space Shuttle main engine welds created by an advanced robotic system.

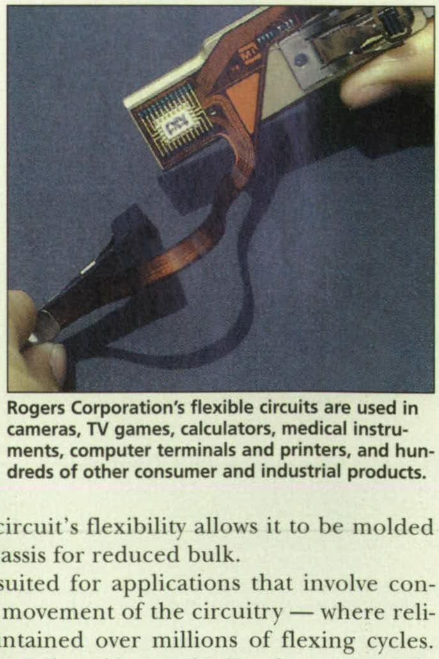
The Nose Knows

A device that detects flammable liquid accelerants used by arsonists employs the same electronic circuitry as a signal conditioning system developed originally for NASA's Langley Research Center. More than 1,000 people are killed by arson fires each year in the U.S. The first step in battling arson is determining the cause of a fire. The spinoff device is proving helpful in post-fire detection of gasoline, benzene, and other combustible accelerants used by arsonists to speed up fire spread.

The Electronic Nose® is a vapor and gas detector manufactured by Grace Industries of Transfer, PA. It senses the presence of accelerants several days after a fire. The device is powered by a rechargeable battery and requires no special training to operate. The device is held about an inch from the suspect material; if an accelerant is present, the device will emit a beeping sound and engage a flashing light. The Electronic Nose can detect minute traces of accelerants, providing speedy detection of physical evidence for use in court.

Widely used by police and fire departments, the device is also used by insurance companies, federal/state agencies, and in university criminal justice courses. It also can be used to detect hazardous fumes, enabling location of gas spills and gas leaks.

Flexible Uses



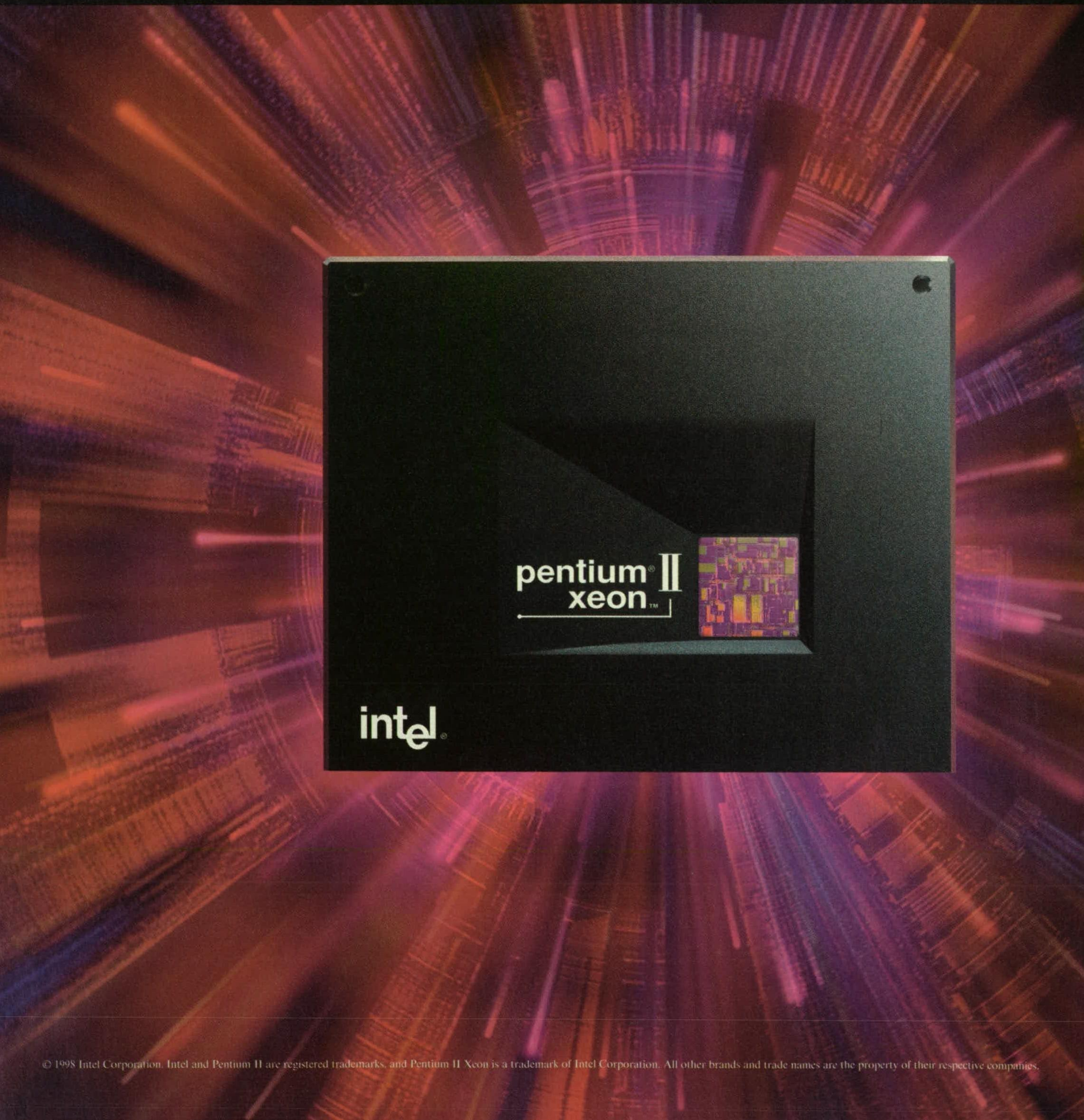
Rogers Corporation's flexible circuits are used in cameras, TV games, calculators, medical instruments, computer terminals and printers, and hundreds of other consumer and industrial products.

First used on military aircraft and missiles, where size, weight, and reliability are of utmost concern, flexible circuits now are being used in a range of commercial applications and space systems. Flexible circuitry is an arrangement of printed wiring that interconnects the components of an electronic system. The circuit's flexibility allows it to be molded to the shape of a chassis for reduced bulk.

The circuits are suited for applications that involve continuous or periodic movement of the circuitry — where reliability must be maintained over millions of flexing cycles. The flex circuits are produced by combining three materials: an insulating plastic film, a metallic conductor such as copper foil, and an adhesive — one of several types of polymers

Continued on page 24

Work [wond



40 Years of Innovations

Continued from page 20

— to bind the insulator and the conductor onto a laminated circuit.

LARC-TPI is a thermoplastic polyimide resin that is being used — under an exclusive license from NASA — by Rogers Corporation's Circuit Material Div. in Chandler, AZ to produce laminates. Langley Research Center developed the advanced structural adhesive by chemically altering the structure of the linear polyimide to improve its characteristics and eliminate processing problems. The result was LARC-TPI.

In its initial commercial application by Rogers Corp., it was used as the adhesive that binds the insulating film Kapton® to copper foil conductor material in the manufacture of flexible circuits. The Rogers product line spans flexible circuits for electronic watches, cameras, TV games, calculators, burglar alarms, medical instruments, test equipment, automotive fuel controls, pollution controls, CB radios, pagers, and antennas.

Controlling the Energy Hogs

Electric motor drive systems such as AC induction motors consume more than half of all electricity used in the U.S., and more than 70 percent of all electricity used in industrial applications. A Hackensack, NJ-based company — Power Efficiency Corp. — came to the rescue with soft-start energy-saving motor controllers developed from NASA technology.

The technology behind this motor controller for AC induction motors was developed by NASA and licensed to Power Efficiency Corp. for commercial applications.

Power Efficiency Corp. was specifically formed to manufacture and market products exclusively developed from NASA technology. The original idea for the three-phase power factor controller with induced electric and magnetic fields sensing came from Marshall Space Flight Center, and was patented by NASA in 1984. Power Efficiency later licensed the technology and used the electronic boards that represent the NASA-developed technology to assemble three different motor controllers. The three products — Power Commander, Performance Controller℠, and Energy Master — have been purchased by customers such as Ford Motor Co. and Caesars Atlantic City.

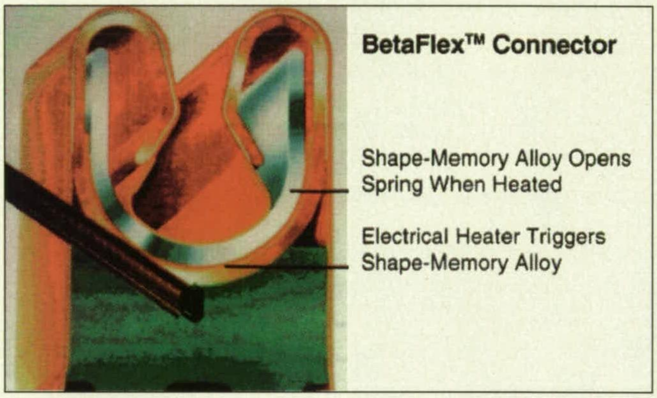
The company's Power Factor Controller (PFC) reduces excessive energy waste in AC induction motors by providing a reduced voltage start, reduced energy consumption, and improved power factor. Volts, amps, and watts are reduced, so motor life is increased. The motor controller is used in industries where motors operate under variable loads, including elevators and escalators, machine tools, intake and exhaust fans, oil wells, conveyors, pumps, and compressors.

Power Efficiency Corp. is now a public corporation traded on the NASDAQ.

1990s

A New Connection

Beta Phase of Menlo Park, CA, offers designers of high-performance digital systems "a new tool to help them do more in less space at less cost." The tool is a line of BetaFlex™ connectors/sockets that connect multichip modules and high-density ceramic packages to printed circuit boards. The products enable designers to gain up to 40% more board space and provide 100 signal lines to the inch.



The new connector technology actually incorporates two well-proven technologies: photolithography to etch the contacts onto flexible circuits, allowing a greater number of contacts in a given area; and shape memory alloy technology, represented by a nickel-titanium element within the connector. When a low-voltage power supply heats the alloy, it opens the connector's spring, allowing the mating printed circuit board to be inserted with zero force.

The shape memory technology originally was discovered in 1962 by the Naval Ordnance Laboratory, but few practical applications emerged. NASA revived interest in the technology in the 1970s and 1980s with projects involving further research on the shape memory properties of nickel-titanium and procedures for processing the alloy. NASA's work led to wider adoption of the technology, and brought about practical applications such as BetaFlex.

In 1990, Beta Phase and Molex, a leading manufacturer of electronic connectors in Lisle, IL, signed an agreement whereby Molex purchased Beta Phase, acquiring the right to become the source for Beta Phase connectors.

Circuits That Really Stack Up

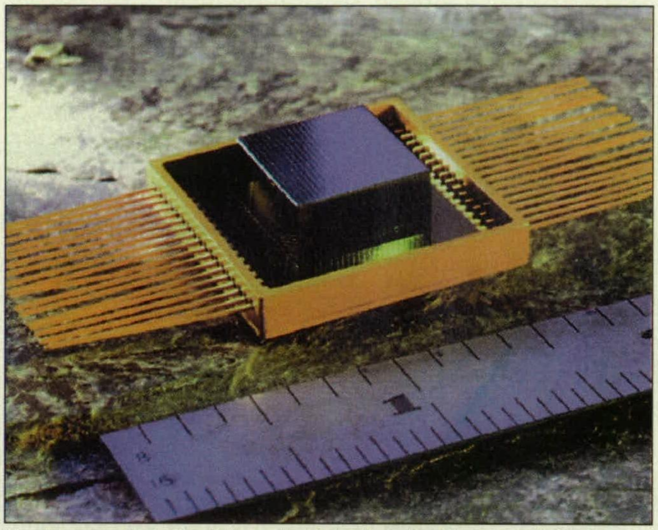
Irvine Sensors Corp. (ISC) of Costa Mesa, CA, invented the process of stacking integrated circuits into a cube. Called a Memory Short Stack™, the result is a three-dimensional semiconductor package in which dozens of circuits are stacked on top of each other to form a cube. The cubing technique provides faster processing speeds, higher levels of integration, and lower power requirements than conventional chip sets. It also reduces the height of memory-intensive systems dramatically.

The innovative process was developed under NASA and

Department of Defense contracts. The Memory Short Stack received a 1993 NASA Award of Innovation as a major advancement in high-density computer electronics. ISC began developing the technology in the early 1990s, and DOD contracts led to the development of a "full stack" version.

The height of the full stack, however, was too great for the multichip packages employed in airborne and spaceborne systems, so the company began developing the Memory Short Stack concept. The stack is fabricated by vertical assembly of integrated circuits, thinned to as little as seven-thousandths of an inch, and extremely thin layers of laminate. Typically, cubes have between 40 and 50 integrated circuits.

The technology has been introduced into a broad range of commercial applications. NASA has awarded ICS eight Phase I and five Phase II SBIR contracts, including an ongoing project with the Jet Propulsion Laboratory to evaluate chip-stacking for space systems. The NASA contracts contributed greatly to the commercialization of the cubing technology. One contract, from NASA's Goddard Space Flight Center,



The Memory Short Stack is a cube-shaped stack of integrated circuits.

involved using the Memory Short Stack in a spaceborne data recorder. The project called for designing the short stacks so that they would be compatible with industry-standard attachment techniques. This made Memory Short Stacks usable in virtually all types of electronic assemblies.

A Question of Integrity

NASA's Langley Research Center has developed devices and procedures for detecting cracks, corrosion, and disbonds during aircraft service inspections as part of NASA's Aircraft Structural Integrity program, which addresses ways to enhance the safety of older commercial jets by improving the structure inspection techniques.

The CrackFinder, one of the devices developed under this program, is an electromagnetic probe for nondestructive evaluation (NDE) that is used in rapidly scanning aircraft skins for surface breaks. The device is based on eddy current technology that provides extreme sensitivity to fatigue cracks in aluminum alloy plates. An eddy current is an electrical current induced by an alternating magnetic field.

The device incorporates an innovative self-nulling feature, which allows the device to automatically recalibrate to zero so that each flaw detected produces a reading. When the probe is placed on a flaw-free metallic object, its output is nulled automatically. The presence of a flaw causes a distinctive probe output amplitude. A bargraph display shows crack severity.

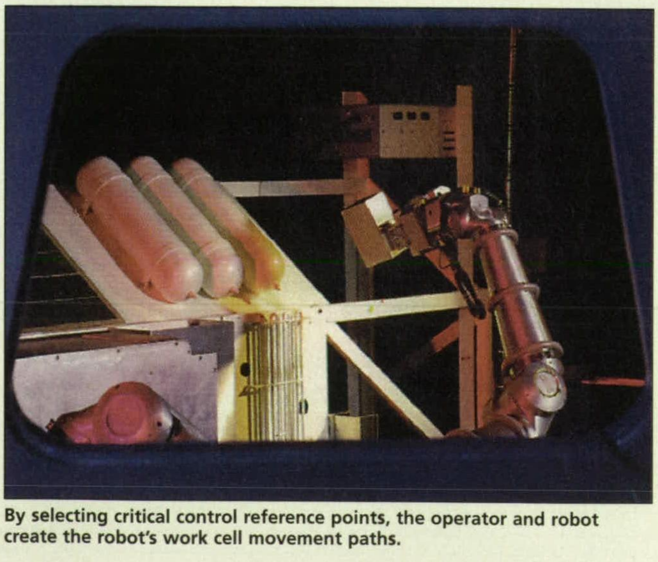
The CrackFinder, developed to scan aircraft skins for surface breaks, is used in industrial fatigue detection.

The CrackFinder was commercially licensed by Krautkramer Branson (KB Instruments) of Lewistown, PA, a subsidiary of Emerson Electric Co. The company says that the innovative design of the device makes it more affordable than conventional eddy current instruments. It also weighs only nine ounces and allows installation of multiple probes in inaccessible locations.

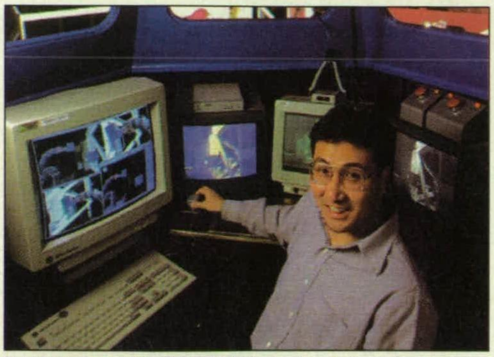
The market for the device goes beyond the aircraft market. Steel structures, ski lifts, and other structures can be scanned for fatigue detection.

A Virtually Dangerous Job

A leader in 3D graphics-based factory simulation, telerobotics, and virtual reality software, Deneb Robotics of Auburn Hills, MI, offers TELEGRIP™ software, which provides a 3D graphical interface for previewing, interactive



By selecting critical control reference points, the operator and robot create the robot's work cell movement paths.



Dr. Won Soo Kim, TELEGRIP inventor, remotely operates a robot.

programming, and real-time remote control of robotic devices. Operators use the system for safe, quick, and efficient remediation of hazardous environments from a single point of control without being subjected to operator hazards.

Operators can preplan and optimize robot trajectories before the program is generated using 3D kinematic models of the robot and work space. TELEGRIP verifies the geometries and updates the model to adjust the environment in real time. A Video Overlay Option utilizes video to calibrate 3D computer models with the actual environment. The technique is useful for on-line planning applications or teleoperations in remote, hazardous, or complex environments such as space, undersea, or in nuclear sites, where conditions may be unknown or change suddenly.

The Video Overlay Option is the result of a project with NASA's Jet Propulsion Laboratory (JPL), which developed a virtual reality calibration technique for accurate matching of a graphically simulated environment in 3D geometry with actual video camera views. The system was designed for predictive displays with calibrated graphics that overlay in live video for telerobotics applications. The system allows the user to designate precise movements of a robot arm before sending the "execute" command.

Since 1976, *NASA Spinoff* has featured many down-to-earth applications of NASA technologies. To learn more about how NASA technologies affect our everyday lives, visit the *Spinoff* web site at: www.sti.nasa.gov/tto/spinoff.html

To Contact Profiled Companies, Call:

Deneb Robotics	810-377-6900
Irvine Sensors Corp.	714-549-8211
Krautkramer Branson	717-242-0320
Molex, BPS	650-688-7400
Power Efficiency Corp.	201-488-4040
Robotics and Automation Corp.	612-572-0707

Next Month:

NASA Technologies Used in Environmental Management

Looking Ahead ...

• Carbon-based electronic components that are at least 100 times smaller than those used in silicon chips can be made in years to come with tiny carbon wires, according to Dr. Deepak Srivastava of NASA's Ames Research Center and Dr. Madhu Menon of the University of Kentucky. Nanotube wires can be connected by pentagons and heptagons at wire junctions. The carbon nanotubes are molecular-sized pipes made of carbon atoms. The junctions where nanotubes with different electronic properties meet in an atomically precise way could be the prototypes of molecular electronic switching, transistor, and amplifying components used in computer chips. Nanotubes soon will be available commercially in small quantities. Grown in long ropes, they are likely to be the strongest fiber ever made and will be about 1/6 the weight of steel.

For more information, visit the web site at: http://science.nas.nasa.gov, or call John Bluck of NASA Ames' Public Affairs Office at 650-604-5026.

• The Mid-Atlantic Technology Applications Center (MTAC), one of NASA's six Regional Technology Transfer Centers (RTTCs), has begun a Next Generation Sensors Initiative (NGSI) to help companies take advantage of federal and university research to develop new products and processes. The goal is to increase U.S. competitiveness by ensuring that U.S. companies have the benefit of the most advanced R&D in each area of sensor technology, and that the time from idea to market is reduced to the greatest extent possible.

The sensors and instrumentation industry is vital to both the health of the U.S. economy and defense preparedness. Worth more than $12 billion and employing 135,000 in the U.S. alone, it is composed of five segments: sensors and transmitters, communication networks, control and display stations, control software, and final elements, which are the devices that manipulate the process variable.

The goal of the NGSI is to extend the R&D capabilities of U.S. sensors and instrumentation companies by facilitating access to federal and university research. NGSI combines the needs, talents and resources of three groups in a collaborative effort to improve the productivity of the industry: companies that use sensors to manufacture products; manufacturers of sensors; and federal, state and private R&D laboratories. MTAC's role in NGSI is to work with the user community to identify sensor technology needs; match needs with technology or technical expertise; develop collaborative research projects; solicit financial commitments; manage R&D projects; and disseminate results.

Many technical challenges will need to be met, including the development of smaller sensors (MEMS, NEMS, and PEMS), multivariable sensors, faster and more powerful computer processors, environmentally hardened sensors and communications (weatherproof, radiation-resistant), lighter power supplies, smart sensors and final elements, and integrated expert systems for display.

NGSI benefits for manufacturers include needs and market identification, shared cost for R&D, increased access to a greater variety of R&D, and larger potential for success. Benefits for users include rapid solutions to technical challenges, input into solutions resulting in more satisfactory applications, and better prototype testing. For government and university R&D facilities, the benefits are shared cost for sensor R&D, access to industry expertise, and built-in commercialization strategy through partnerships with industry.

For more information, call John Bacon, MTAC Business Development Specialist, at 412-383-2500.

Commercialization Opportunities

Delta-Doped CCDs as Low-Energy-Particle Detectors

These devices, developed previously for imaging ultraviolet light, are also useful as detectors of electrons and other charged particles with kinetic energies as low as about 100 eV.
(See page 48.)

Matrix and Coating Polymers for Composite LOX Containers

Two polymers are suitable as matrix and coating materials for tanks and pipes carrying liquid oxygen. The polymers are amenable to processing by common fabrication techniques.
(See page 60.)

Passive Capture Joint With Three Degrees of Freedom

This joint can be useful in a variety of applications, including replacing the joints commonly used on trailer-hitch tongues and temporary structures, such as crane booms and rigging.
(See page 65.)

Microscopic Heat Exchangers, Valves, Pumps, and Flowmeters

Micromachining processes, similar to those used in producing ICs, could be used to produce microscopic forced-flow heat exchangers, flow channels, peristaltic pumps, and other related components. The parts would be made largely from silicon and would feature highly effective heat transfer.
(See page 66.)

Miniature Side-Bore Sample-Acquisition Mechanism

A mechanism encased in a penetrator dart is designed to collect soil samples in remote, cold, and otherwise hostile environments. Originally designed for exploration of Mars, the mechanism can be used on Earth to study remote and hazardous regions.
(See page 67.)

Emergency-Shutoff Valves Would Be Triggered by Accelerations

Automatic valves are proposed that would shut off under abnormally large acceleration. This feature would be important in earthquakes, explosions, and vehicular accidents to shut down spilling flammable, toxic, and/or valuable liquids.
(See page 68.)

Automatic Thermal Switches With No Moving Parts

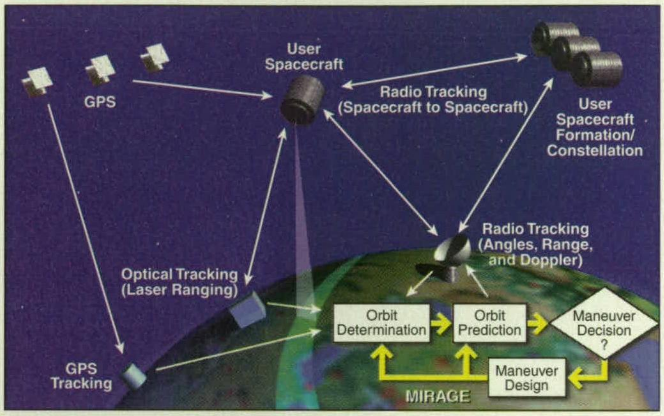
The proposed switches would operate automatically, require no power supply or controls, consume no materials, and create no vibrations. Operation is based on pressure of carbon dioxide gas sealed inside the switch.
(See page 72.)

Special Coverage: Graphics & Simulation

Program Performs High-Precision Spacecraft-Constellation Navigation

NASA's Jet Propulsion Laboratory, Pasadena, California

The Multiple Interferometric Ranging Analysis using GPS Ensemble (MIRAGE) computer program processes spacecraft-tracking data to determine orbits of single satellites, or of multiple satellites with intersatellite tracking, to within position errors as small as a few centimeters (see figure). MIRAGE also targets spacecraft maneuvers (changes of velocity) to precision higher than that achievable by current spacecraft hardware. Tracking data that MIRAGE can utilize include Global Positioning System (GPS) pseudorange and phase, data from general range and Doppler measurements, angles, data from optical measurements, and data from very-long-baseline interferometry (VLBI). The modular program structure enables addition of other tracking data types for specific user spacecraft.



MIRAGE serves as a navigation system for multiple Earth-orbiting spacecraft. This diagram summarizes its functions.

MIRAGE implements a variety of geometrical and dynamical models that the user can control. A pseudo-epoch-state filter in MIRAGE smooths over data arcs selectable by the user, yielding robust solutions in the presence of bad tracking data and modeling errors. Operation is simplified through a system of interdependent and automated Unix and Perl scripts or through interactive X-Window menu-driven software wrappers. MIRAGE could be particularly useful for navigating multiple satellites to maintain them in a constellation for global telecommunications.

This program was written by Bobby G. Williams, Peter J. Wolff, Rick F. Sunseri, Theodore R. Drain, James B. Collier, Tseng-Chan Wang, and Joseph R. Guinn of Caltech for **NASA's Jet Propulsion Laboratory.** *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Mechanics category.*
NPO-20287

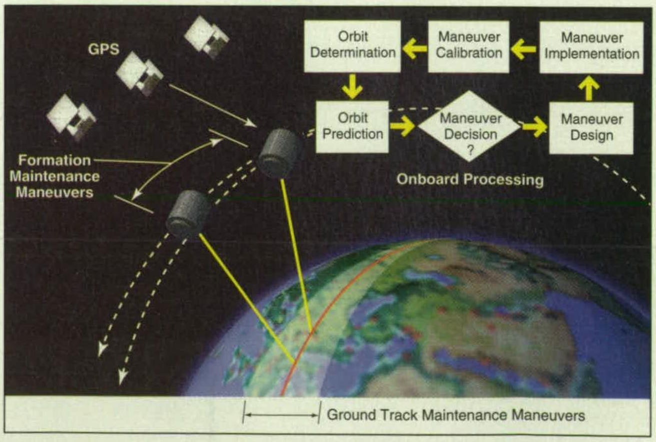
Software for Navigation of a Spacecraft Flying in Formation

NASA's Jet Propulsion Laboratory, Pasadena, California

The Spacecraft Autonomous Navigation System using GPS for Earth Orbiters (SANS-GEO) computer program is designed to perform the navigation calculations that will enable the New Millennium Program's Earth Orbiter-1 (EO-1) spacecraft to fly in formation with the Landsat-7 (LS-7) satellite in orbit around the Earth. Scheduled to be launched in May 1999, the EO-1 will be required to follow 450±50 km behind the LS-7, and to keep its ground track within 3 km of the LS-7 ground track. Using data from an onboard Global Positioning System (GPS) receiver and empirical (purely kinematic) GPS navigation algorithms, SANS-GEO would compute parameters of the EO-1 orbit; these parameters would include rates of atmospheric-drag-induced decay. SANS-GEO would then utilize these parameters, along with the corresponding parameters and with maneuver plans generated remotely for the LS-7, to determine EO-1 velocity-change maneuvers needed to satisfy absolute orbital constraints (e.g., ground-track-repeat requirements) and/or relative orbital constraints (formation-flying requirements). The computed velocity-change maneuvers would be converted into commands for the EO-1 attitude-control system and thrusters.

This program was written by Joseph Guinn of Caltech for **NASA's Jet Propulsion Laboratory.** *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Mechanics category.*

This software is available for commercial licensing. Please contact Don Hart of the California Institute of Technology at (818) 393-3425. Refer to NPO-20190.



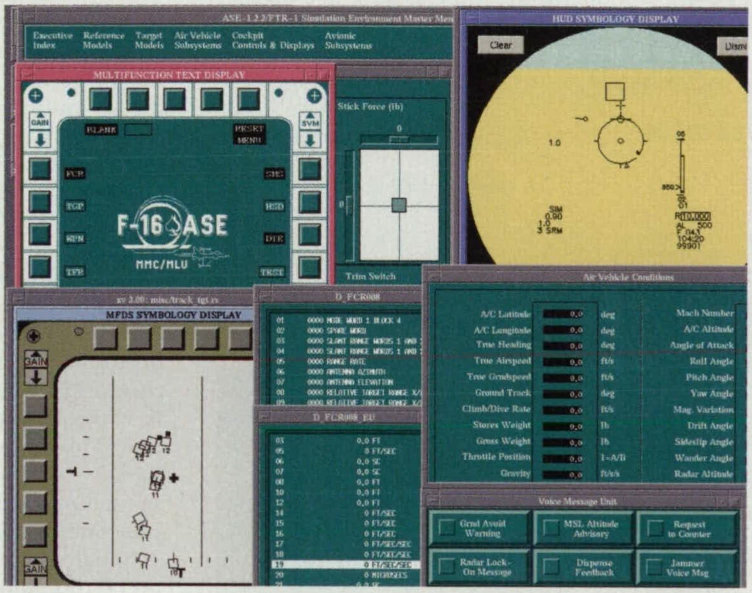
The **Spacecraft Autonomous Navigation System** depicts the extent of the onboard processing.

SL-GMS The Complete Dynamic Data Visualization Tool for ATMS Applications

WEB ENABLED

A flexible, easy-to-use tool for developing animated displays for real-time applications

SL-GMS is a proven dynamic graphics engine, with the features needed to quickly create dynamic displays for real-time applications. Designed for easy integration into interactive environments, SL-GMS offers functionality well-suited to applications that contain a complex network of active data.



The ASE has implemented SL-GMS for simulation of Multi-Function Display and Head-Up Display cockpit systems

FUNCTIONALITY

- Non-programmatic development of complete graphical user interfaces
- Support of imported vector and bitmap backgrounds
- Tracking objects across background maps (GPS)
- Dynamic vector objects (lines, circles, etc.) that change attributes to represent changing application variables
- Dynamic display of application data through plots and trends

FLEXIBILITY

The SL-GMS Draw component is a powerful graphical editor equipped with advanced capabilities for creating custom screen objects, as well as specifying the dynamic behaviors of those objects directly within the editor. SL-GMS greatly simplifies the building of layered applications. SL-GMS offers State Class Libraries that allow developers to easily create multi-layered sets of screens to control and animate complex application displays. Because SL-GMS encapsulates the basic elements of dynamic screens into objects, users are freed from the complex programming logic that is otherwise required to manage constantly updating layers of screens.

The SL-GMS real-time dynamics graphics engine embodies years of optimization in handling large data sets. This allows many different techniques for achieving maximum performance under diverse application requirements.

- Customizable editor
- Cross platform portability
- Support of Motif widgets and NT control objects
- Under Windows NT, SL-GMS can be integrated as an ActiveX control component
- SL-GMS can be seamlessly integrated and displayed in a Web page via a Netscape Plug-In
- Smooth pan, zoom and decluttering
- Integration with live video displays for real-time monitoring

COMPONENT AND WEB-BASED APPLICATION SUPPORT

SL-GMS dynamic graphics are available within any of the following component-based solutions: ActiveX, Java Bean, Netscape Navigator Plug-In or pure Java applet.

SL
Sherrill-Lubinski

SL Corporation
Suite 110 Hunt Plaza
240 Tamal Vista Boulevard
Corte Madera, California 94925
415/927-1724

http://www.sl.com

Simulations in Support of Towed Flight Demonstration

Two independent simulations run simultaneously to study towed-aircraft response before flight.

Dryden Flight Research Center, Edwards, California

The Eclipse flight project was established to demonstrate a reusable-launch-vehicle concept developed by Kelly Space and Technology, Inc. An F-106 delta-wing aircraft was chosen as the towed vehicle, and a C-141A transport-type airplane was selected for the towing vehicle. These airplanes are shown in Figure 1. Dryden Flight Research Center was the test organization with responsibility for safety of flight on the Eclipse project.

To enhance safety of flight, simulations of the two airplanes were implemented along with a simple mathematical model of a tow rope. A computational simulation of an F-106 airplane had been implemented at Langley Research Center to support some vortex-flow flight experiments, and this simulation was revived at Dryden. The C-141 simulation was adapted from an existing B-720 simulation at Dryden by replacing the mathematical model of the aerodynamics of the B-720 airplane with linear aerodynamic coefficients based on the performance of the C-141 airplane. The mathematical model of the B-720 engine was modified with a thrust multiplier to match the C-141 static sea-level thrust. In addition, the simulation was updated with C-141 weight, inertia, and center-of-gravity data. Existing simulation cockpits were used without modification.

The tow-rope model assumes that the tow rope lies on straight line between the two airplanes. On the basis of results from laboratory tests, the rope tension was modeled as quadratic in elongation and linear in elongation rate. This tow-rope model was verified initially by implementing it in a glider simulation and having a glider pilot subjectively evaluate the performance.

Initial studies were performed with the F-106 simulation alone. In these studies, it was assumed that the C-141 airplane was a point mass that would be unaffected by the forces on the tow rope. C-141 takeoff trajectories were generated and recorded in the C-141 simulation. These trajectories were played back in the F-106 simulation to study the takeoff performance of the towed F-106. This first cut showed some interesting results. The F-106 performance on tow was quite different from that of a sailplane. There appeared to be a lower and an upper bound on the tow angle between the two airplanes. Flight beyond these bounds would cause divergent pitch and sometimes roll oscillations. Fortunately, the oscillation amplitude would increase slowly enough that the pilot was able to recognize the problem and correct for it by flying back within the bounds. The simulation was already providing important information to the flight-test team.

To make the simulation study more realistic, it was decided that simulations of both airplanes should be performed simultaneously. To do this, it was necessary to link two independent six-degree-of-freedom (6-DOF) simulations — essentially creating a 12-DOF simulation. Although this seemed challenging at first, it turned out to be

Figure 1. These **Aircraft Were Used To Demonstrate** the concept of towing a reusable aerospace vehicle to launch altitude.

quite simple. The two simulation computers were linked with a fiber-optic reflective memory interface; this linkage enabled the sharing of airplane positions, velocities, and tow-rope forces between the two simulations.

To obtain consistent results, it was decided to synchronize the two simulations. The frame rates of both simulations were increased to 100 Hz, and flags in shared memory were created to enable the simulations to synchronize by polling. The interrupt driver in the F-106 simulation was used to generate the 100-Hz frame pulse, and the C-141

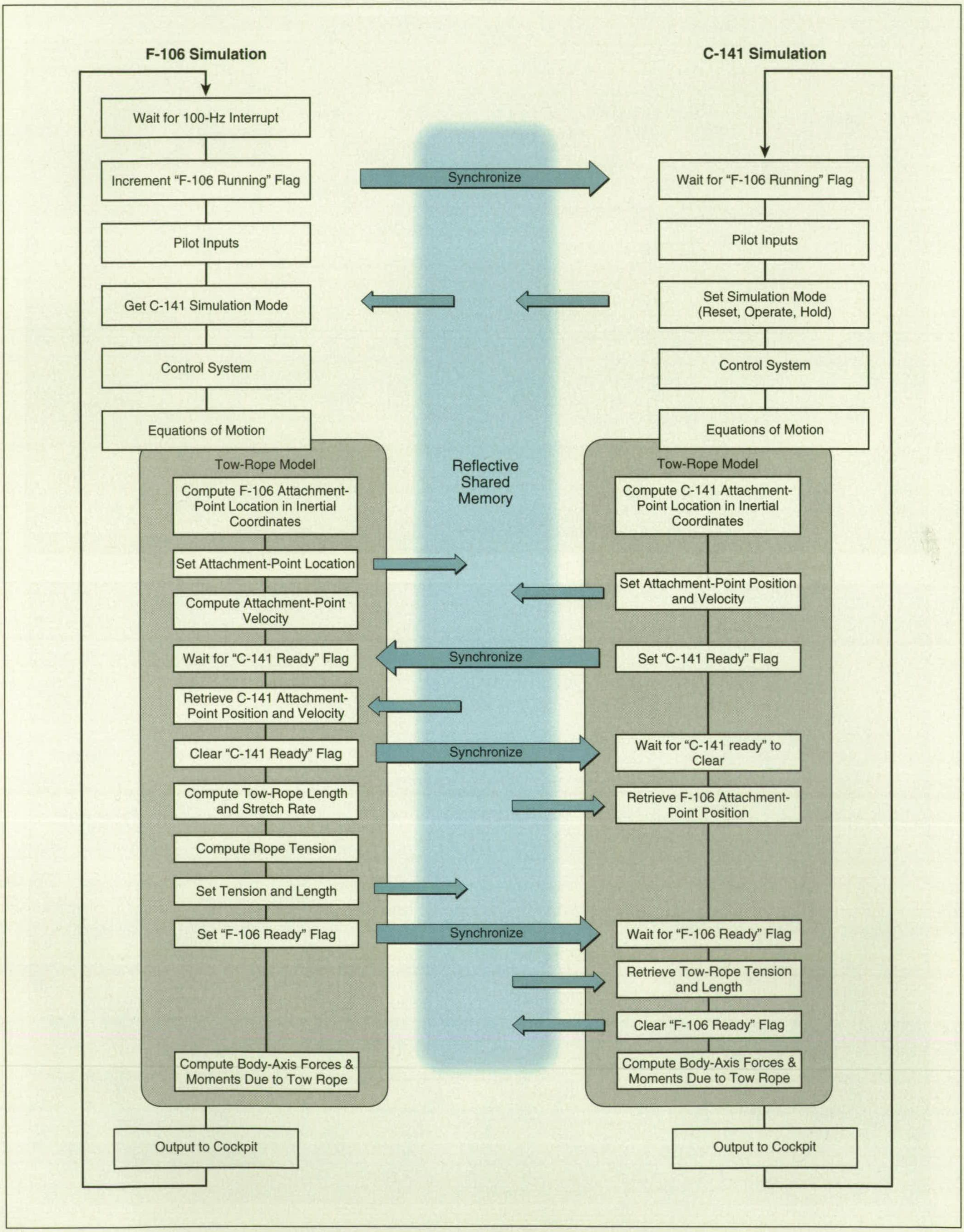


Figure 2. **Simulations of the Towing and Towed Airplanes** were synchronized to obtain consistent results.

simulation simply waited for the F-106 simulation to indicate that a new frame should be started. The synchronization scheme is shown in Figure 2.

The results of the linked simulations confirmed the results of the F-106 simulation. The assumption that the C-141 airplane could be treated as a point mass turned out to be a good one. The C-141 pilot could not feel the effects of the F-106 doing normal small-amplitude maneuvers on tow.

The availability of two independent simulations also afforded a capability to achieve quicker, more productive, simulation sessions. Instead of generating a C-141 trajectory and then preparing and transferring the resulting data for playback in the F-106 simulation, the C-141 pilot could simply hit a "simulation reset" button and immediately try a different takeoff profile. This enabled the F-106 test pilot to quickly get the feel of the towed operation, and soon this pilot's task became easy. This setup also proved valuable for evaluating various failure scenarios during full mission simulation with the control room being fed by a stream of data generated by the simulator and transmitted by pulse-code modulation.

Six towed flights were performed in a demonstration program that was completed on February 6, 1998. Extensive instrumentation was used so that flight results could be compared with simulation results. It turns out that the simulation tow model was good at predicting rope tension, but a little conservative in predicting stability. The F-106 pilot was able to fly to more extreme tow angles before encountering the divergent oscillations. Part of this difference between the simulation and the flight tests may be due to the assumption of a straight tow rope in the simulation. During the flight tests, the tow rope would "sail" and develop significant curvature. In later flights, the tow rope was marked at regular intervals and video images were recorded so that this phenomenon could be studied in more detail. With the flight-instrumentation data and video images, it should be possible to develop a more realistic tow-rope model that can be incorporated into the simulation.

This work was done by Ken Norlin and Jim Murray of **Dryden Flight Research Center** *and Joe Gera of Analytical Services and Materials, Inc. For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Machinery/Automation category. DRC-98-33*

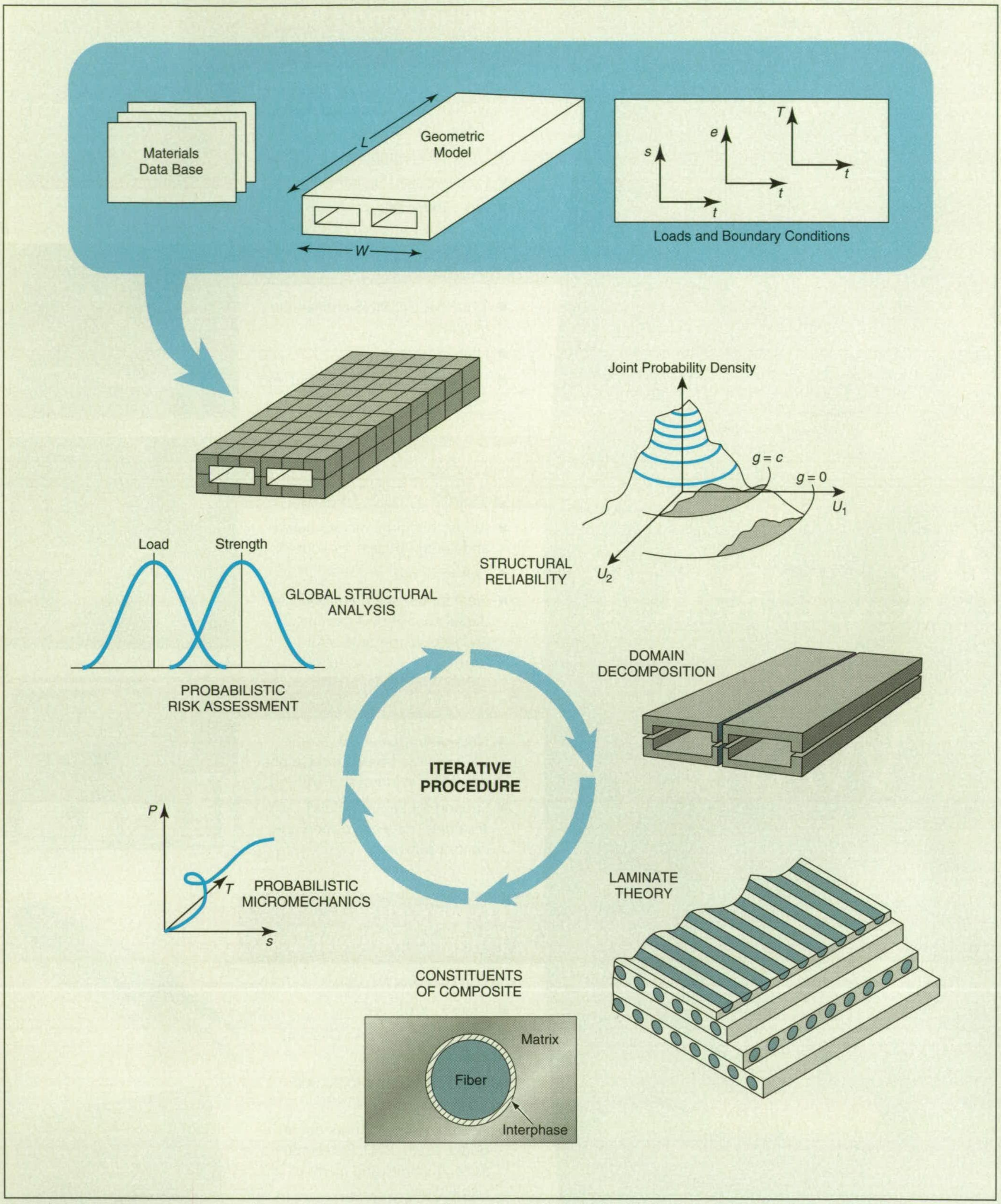
Software for Probabilistic Analysis of Composite Structures

An integrated software package exploits parallel processing to reduce computation time.

Lewis Research Center, Cleveland, Ohio

GENOA is an advanced, completely integrated, hierarchical software package for computationally simulating the thermal and mechanical responses of high-temperature composite materials and of structures made of those materials. The development of GENOA was guided partly by the need for a computational tool that could accelerate the design process while making it possible to avoid designing structures to be unnecessarily heavy and expensive, as they can be when one follows a deterministic approach and uses simple safety factors to account for variability among structural components in the effort to design conservatively. GENOA implements a probabilistic approach in which design criteria and objectives are based on quantified reliability targets that are consistent with the inherently stochastic nature of the properties of materials and structures.

The probabilistic approach to design involves the use of the deterministic basic equations of mechanics in a more-comprehensive analysis in which stochasticity is quantified by use of probability distributions. The methods used to simulate numerically the consequences of probability distributions include the Monte Carlo method and such algebraic methods as first-order reliability, second-order reliability, the mean-value method, or the response-surface method. Probabilistic methods provide measures of the variation of risks of failure with variations in design parameters and properties of materials, thereby making it possible to determine the robustness of a design. Realistic indications of the lifetimes of



Analytical Components Are Integrated in an iterative computational procedure with hierarchical multiple-level parallelism.

structures can be obtained by taking account of such phenomena as low cycle fatigue, cracking induced by flaws, yield and ultimate strengths, creep strength, the operational environment, and damage in service. The economic benefits of using probabilistic methods to design and analyze structures include (1) reduction of weights (and thus reduction of initial costs) of structures, (2) reduction of operating and service costs, (3) reduction of failure rates, and (4) capability to generate predictable maintenance schedules.

GENOA provides computational integration and parallel processing for probabilistic mathematics and for mathematical models of composite materials and structures. Massively parallel processing enables GENOA to function in the face of the inherent complexities of high-temperature composite-material structures. Dynamic load-balancing optimization techniques are used in GENOA to minimize processing time. To perform a

given analysis, GENOA takes about 1/20 of the processing time of a typical older serial-processing program developed for the same purpose.

GENOA features a highly modular architecture that makes it fast, accurate, and user-friendly. Hierarchical analytical components are implemented by software modules that contain highly specialized analysis codes (including nonlinear finite-element and micromechanical-analysis codes, for example). These components are integrated in a computational procedure that involves iteration between microscopic and macroscopic scales (see figure). The integration is effected by use of a graphical user interface (GUI) and an executive controller system (ECS). The menu-driven ECS connects the modules. The GUI provides a seamless transition from description of a problem through implementation of the solution process to post-processing graphical display of solution data. The value of integration cannot be overemphasized: in GENOA, it is easy to import data from another structural-analysis or computer-aided-design program to describe a problem, whereas in most finite-element-analysis programs, such importation is difficult.

Analytical performance is enhanced by a capability to size adjacent problem domains dynamically to minimize processor waiting times. Central-processing-unit time is reduced and memory limitations are overcome by introduction of an effective optimized parallelization algorithm characterized by machine-independent multiple-instruction/multiple-data (MIMD), single-instruction/multiple-data (SIMD), and Open Software Foundation (OSF) types of computer architecture. Hierarchical stochastic simulation is performed to accommodate the numerous levels of uncertainty present in environmentally dependent properties of materials, enabling the user to identify quickly the most probable critical point of a design.

This work was done by Frank Abdi, Yvgeniy Mirvis, Jafar Hadian, and Kenneth J. Newell of Alpha STAR Corp. for **Lewis Research Center.** *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Materials category.*

Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Lewis Research Center, Commercial Technology Office, Attn: Tech Brief Patent Status, Mail Stop 7–3, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-16543.

Finite-Element Model of Piezoelectric and Thermal Effects

Layerwise finite elements enable modeling of responses of "smart" piezoelectric composite structures.

Lewis Research Center, Cleveland, Ohio

A mathematical model that includes layerwise finite elements has been developed for use in numerical simulation of the coupled electrical, mechanical, and thermal responses of composite plate structures that incorporate piezoelectric sensors and actuators. Typically, the sensors and actuators in these so-called "smart" structures consist mainly of patches or layers of piezoceramic material. These "smart" structures can be used to sense and/or induce stresses, strains, and/or displacements in themselves or in larger structures of which they are parts. In one important class of potential applications that is particularly relevant to the present mathematical model, the piezoelectric actuators would be used to counteract thermal distortions.

The mathematical derivation of the model begins with the representation of coupled mechanical, electrical, and thermal responses at the material level by a set of simultaneous equations that include (1) the equation for mechanical equilibrium in the presence of stress; (2) Maxwell's equation for the conservation of electric displacements; and (3) the constitutive equations that express the relationships among strain, electric field, and temperature in a thermopiezoelectric material. The mechanical displacement, electric potential, and temperature are assumed to be fields that are layerwise continuous through the thickness of a given laminate or plate structure. This assumption provides the capability to capture locally induced piezoelectric effects, leading to increased accuracy in prediction of stresses, especially in a laminate that is thick and/or that exhibits strong through-the-thickness thermal and elastic inhomogeneities.

The layerwise formulation leads to a corresponding finite-element formulation for a bilinear plate element. The finite-element equations can be put into

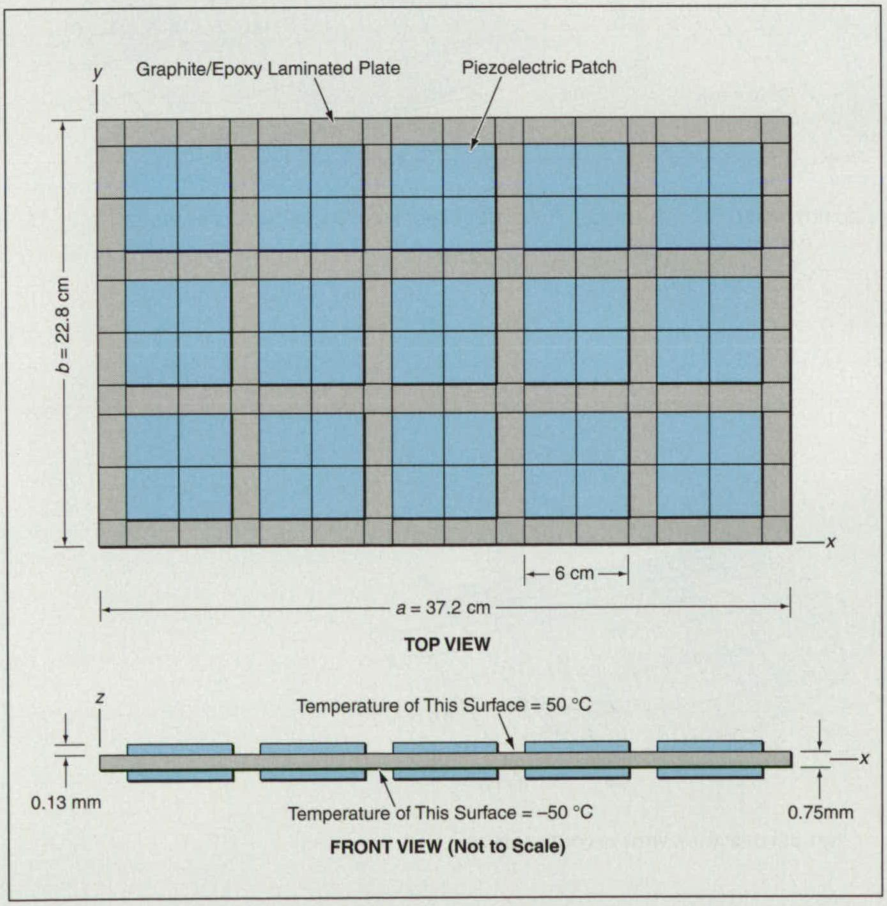


Figure 1. This **Graphite/Epoxy Plate With Piezoceramic Patches** on its upper and lower surfaces was considered to be simply supported at its right and left edges, and subject to a thermal gradient through its thickness.

a compact matrix form, with the electric potential partitioned into active (applied) and sensory components. The advantage of this form is that the unknown variables (displacements and sensory electric potentials) appear on the left side, while the known quantities (mechanical loads, thermal loads, electric charges, and applied voltages) appear on the right side of the equation. The partitioned equations can be uncoupled into an independent equation for mechanical displacements and another independent equation for sensory electric potentials.

In a test case, the model was applied in a simulation of the behavior of a thermally loaded [0°/±45°] graphite/ epoxy laminated plate with a total of 30 piezoceramic patches mounted in symmetrical patterns on the top and bottom surfaces. The plate (see Figure 1) was considered to be simply supported along its *y* edges, and to be subjected to a thermal gradient from a temperature of 50 °C at its top surface to –50 °C at its bottom surface. The model was used to calculate the distortion caused by the thermal gradient alone, plus the combined effects of the thermal gradient and piezoelectric actuation. The numerical results, plotted in Figure 2, indicate that application of equal potentials of 70 V to the upper and lower piezoelectric patches counteracts the thermal distortion to such an extent as to reduce the centerline deflection to near zero.

This work was done by Ho-Jun Lee of **Lewis Research Center** *and Dimitrios A. Saravanos of Ohio Aerospace Institute. For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Mechanics category.*

Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Lewis Research Center, Commercial Technology Office, Attn: Tech Brief Patent Status, Mail Stop 7–3, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-16537.

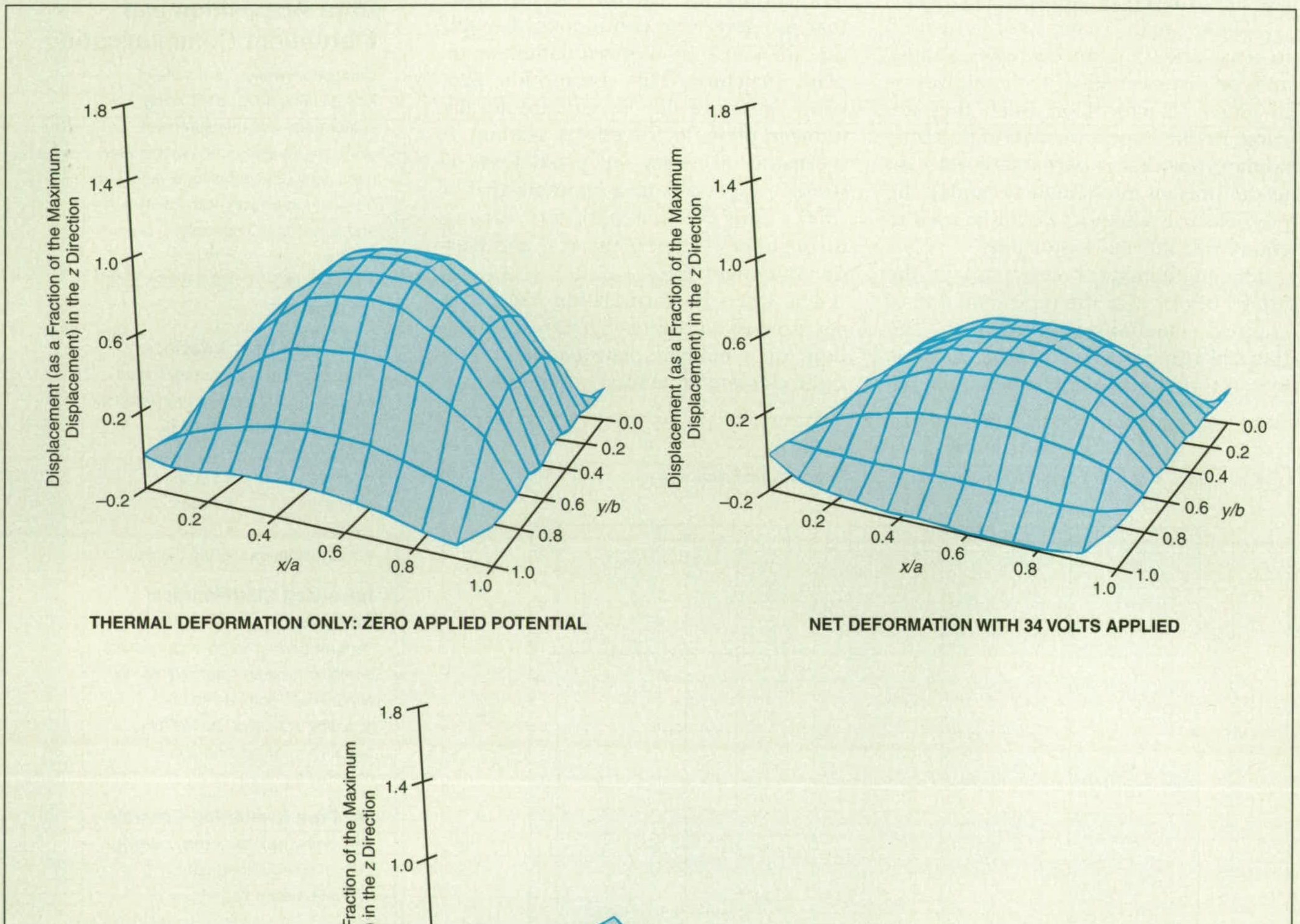


Figure 2. **Displacements of the Plate** of Figure 1 were computed by use of the mathematical model to illustrate the capability of the model and the use of piezoelectric actuation in a "smart" structure to counteract thermal distortion.

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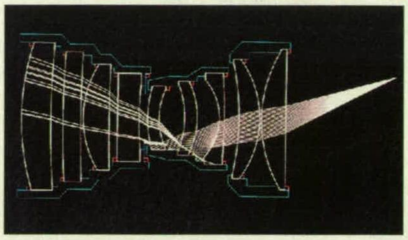
For More Information Circle No. 521

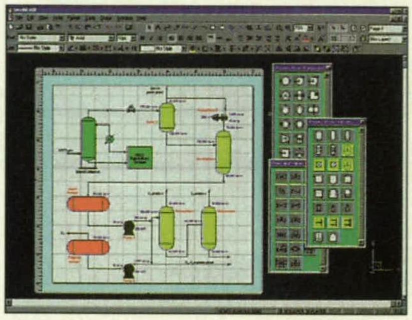
Special Coverage: Graphics & Simulation



Breault Research Organization, Tucson, AZ, has released ASAP™ 6.0 **optical engineering and analysis software** that allows users to design, analyze, and prototype optical systems in one program. Features include The Builder for constructing geometry using standard spreadsheet navigation features; IGES Translator; and Radiant Sources, which allows direct import of Radiant Imaging's measured sources for modeling filament, plasma, and gas discharged sources.

The software features four modules: ASAP/Basic, which processes up to 300 objects for non-imaging analysis; ASAP/Pro, an expanded version of ASAP/Basic, for analyzing very large optical system models such as those generated by CAD programs; ASAP/CAD, which imports and exports optical system data from IGES format to ASAP input format for analysis; and ASAP/Optical for coherent imaging functionality and wave optics propagation.

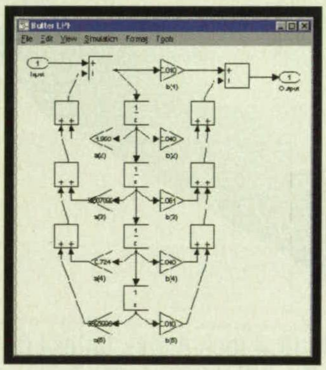
For More Information Circle No. 735



IntelliCAD® 98 **CAD toolset** from Visio Corp., Seattle, WA, allows the use of existing AutoCAD files, commands, and tools by incorporating the DWG file format as its native format. AutoCAD files can be opened and saved without conversion. Compatible with Windows 95/NT, the software enables users to work with multiple open documents, manage drawings with the Drawing Explorer, and modify multiple selected entities.

Users can edit embedded ActiveX objects in place in IntelliCAD drawings; customize menu toolbars and symbol libraries; and create 3D designs, including hidden-line, shaded, or fully rendered photorealistic versions of 3D models with custom-specified surface materials, background settings, and lighting effects.

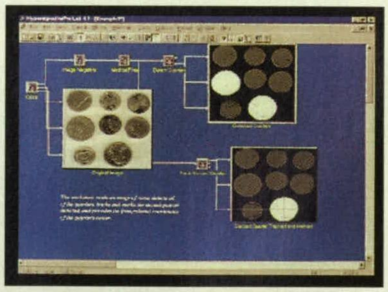
For More Information Circle No. 736



The MathWorks, Natick, MA, has announced an enhanced version of the DSP Workshop **digital signal processing design and simulation software**, which consists of MATLAB, Simulink, Signal Processing Toolbox, and DSP Blockset. The integrated environment includes an array language for algorithm development and a block diagram simulation environment for simulating, testing, and generating code for use on target DSPs.

Enhancements include improvements in simulation and code generation efficiency; the addition of a filter realization wizard that simplifies creation of filter structures in the DSP Blockset; and flexible tools for linking external functions into Simulink. The Workshop supports Windows 95/NT, Sun, Hewlett-Packard, IBM, Silicon Graphics, and Digital Alpha workstations.

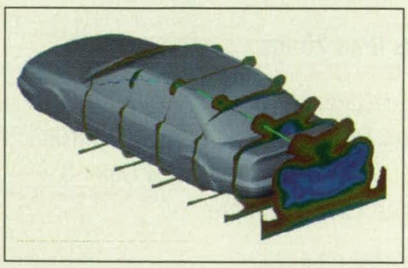
For More Information Circle No. 739



Hypersignal® ImPro Lab™ **graphical image processing software** from Hyperception, Dallas, TX, features 32-bit design, allowing formulation of algorithms derived from an engineer's conceptual frameworks. The integrated image and signal processing environment supports both real-time and simulated image analysis, as well as supporting user-written and user-defined functions and algorithms.

The program allows an image processing algorithm to be graphically constructed, then executes the algorithm depicted in the block diagram at high speed. The user can view images, including full motion and display analysis results such as histograms. The two-level software incorporates a user interface and a library of selected image processing routines. Standard, Professional, and Enterprise Editions are available, all for Windows 95/NT/98.

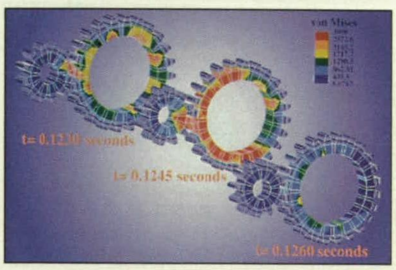
For More Information Circle No. 742



Exa Corp., Lexington, MA, offers PowerFLOW™ Release 3 internal and external **fluid flow simulation software** that incorporates multiplatform availability and CAD universal interfacing with setup, simulation, and post-processing in a single package. The software is suitable for applications including transient and steady-state fluid flows, and employs a fully automatic grid generation. Time-accurate results from realistic transient behavior simulations are provided.

A universal CAD interface allows the use of engineering models from ANSYS, CATIA, MSC/NASTRAN, Pro/ENGINEER, SDRC, Unigraphics, and other CAD programs. Simulations run on Silicon Graphics and Sun Microsystems servers, with set-up and post-processing available on Hewlett-Packard, SGI, and Sun workstations.

For More Information Circle No. 743



Accupak/VE Release 12 **mechanical event simulation for virtual prototyping software** from Algor, Pittsburgh, PA, allows users to simulate real-world behavior of mechanical designs having motion or impact over a defined time period. A coupling feature added to the general contact element enables users to restrict motion in mechanisms. Simulating material damping-related behavior such as shock-absorption is enabled with a new dashpot element.

The general contact element allows the simulation of events involving the interaction of several objects, and enables users to apply multiple element and material behavior values to a model at the same time. The coupling element enables definition of a relationship between parts of a mechanism by specifying the length at which the general contact element stiffens.

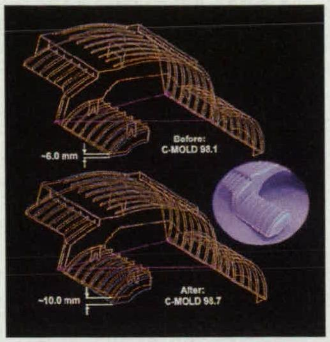
For More Information Circle No. 745

Special Coverage: Graphics & Simulation

Immersive Design, Acton, MA, has introduced IPA 4.0 3D photorealistic **animation and visualization software** that allows design engineers, motion analysis engineers, and technical professionals to visualize and interact with a product design by adding motion and enhanced visual characteristics. The software translates a product designed in a CAD/CAM package into an interactive, 3D animation that can be viewed through Windows 95/NT, sent via e-mail, or downloaded from the web.

The base model, IPA Standards, provides interactive animation; IPA Professional offers photorealistic visualization in real time, as well as raytrace animation and rendering. Both versions feature time-based control of animations; enhanced shadow, true reflection, and anti-aliasing capabilities; and flexibility for rendering and animation window size.

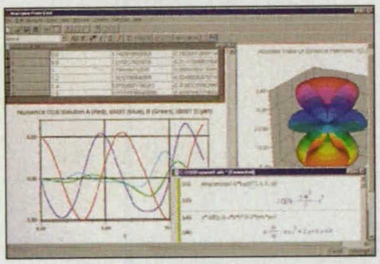
For More Information Circle No. 737



C-MOLD 98.7 **molding simulation software** from C-MOLD, Louisville, KY, features enhancements to shrinkage and warpage simulation, including the ability to incorporate fast-cooling pvT properties for semi-crystalline materials, and the ability to couple layer-based residual stress with orientation-induced thermomechanical properties for fiber-filled materials.

The software calculates layer-based residual stress through the Full-Gap™ thickness of a part. As a part shrinks during cooling, residual stress is caused within the part thickness. The residual stress varies through the thickness because the pressure and temperature histories vary at each layer through the part thickness. C-MOLD determines the orientation and thermomechanical properties at each thickness layer, providing even cooling between core and cavity mold walls.

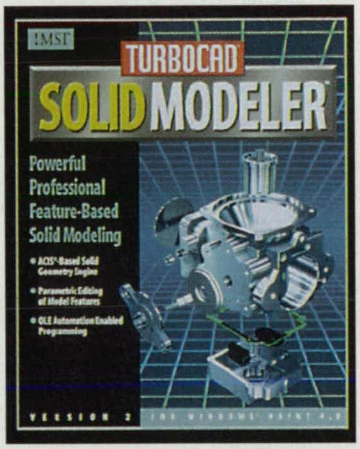
For More Information Circle No. 738



PC Macsyma® 2.3 and UNIX Macsyma 421 numerical, symbolic, and **graphical mathematics software** from Macsyma, Arlington, MA, provide a stochastic mathematics package, improved special functions, enhanced tensor analysis, new polynomial approximation routines, and 2D and 3D FFT routines. The software can plot direction fields and phase plots for ordinary differential equations, histograms, data with error bars, and standard 3D geometric figures.

The PC version is available for Windows 95 and NT, and for Windows 3.1 with some reduction in features. It can be configured for O/S2Warp v4 or Macintosh PowerPC. It incorporates 100 new template buttons and type-in templates. The UNIX version features re-executable scientific notebooks with animated graphics, and text and graphics editing.

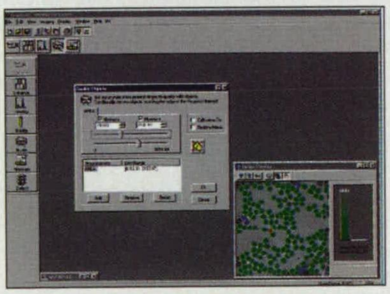
For More Information Circle No. 740



IMSI, San Rafael, CA, offers TurboCAD Solid Modeler v2.0 ACIS®-based **3D modeling software** that allows solid modeling of real-world objects in 3D. Users can conceptualize, construct, and revise product models and virtual prototypes prior to entering the manufacturing process. The program is available for Windows 95/NT.

Features include 32-bit solid modeling; the ability to extrude and sweep 2D objects into 3D geometries; programmable/compliable scripting language; 30 professionally designed models with feature histories; more than 400 part samples; versatile Gouraud, Phong, and raytrace renderer plus textures; and full 2D and 3D constraint system.

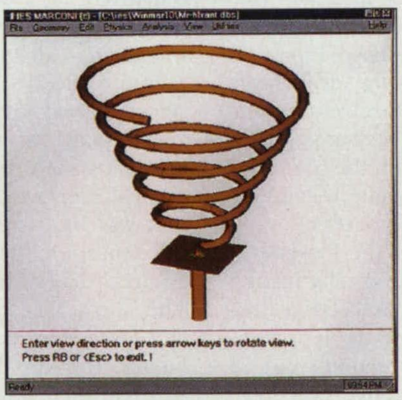
For More Information Circle No. 741



SimplePCI **image processing and analysis software** from Compix, Imaging Systems, Cranberry Township, PA, runs under Windows 95/NT and supports a range of cameras and automated peripheral devices. It can be applied to a range of quantitative imaging applications for data collection and statistics analysis. Images are acquired live from analog video cameras, digital cameras, disk, across a network, from scanners, or from scanning electron microscopes.

The software supports up to 16-bit gray images and 24-bit color images in formats such as TIFF and JPEG. Other features include single- or dual-monitor display; PCI digitizers for high-speed transfers; simultaneous monochrome and color inputs; automated control of multiple devices; XY & Z stage drives; multiple camera capture; and excitation/emission filters.

For More Information Circle No. 744



Integrated Engineering Software, Winnipeg, Manitoba, Canada, has released Marconi 3D high-frequency **electromagnetic field simulation software**, a full-wave simulator that computes various parameters for 3D structures, including near/far fields, radar cross-sections, and Z, Y, S parameters.

The software is based on the boundary element method (BEM) numerical algorithm, and requires no open-region meshing or artificial boundaries that limit FEM solutions. Applications include scattering, radiation, and EMC/EMI design in telecommunications, military, aerospace, and medical industries.

For More Information Circle No. 746

Electronic Components and Circuits

Delta-Doped CCDs as Low-Energy-Particle Detectors

Detection of particles is in addition to traditional use of CCDs as imaging devices.

NASA's Jet Propulsion Laboratory, Pasadena, California

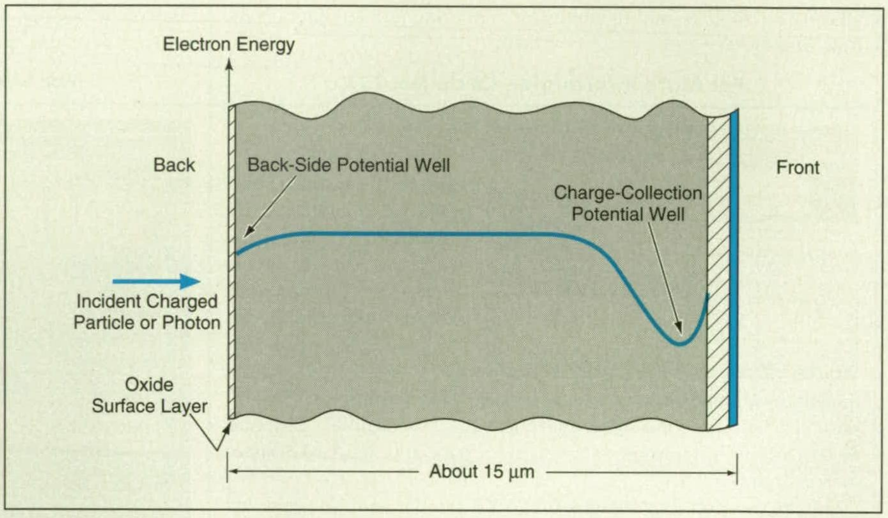
Charge-coupled devices (CCDs) of a type developed previously for imaging in ultraviolet light have been found to be useful as detectors of electrons and other charged particles with kinetic energies as low as about 100 eV. Heretofore, solid-state electronic devices have generally not been useful for detecting particles with kinetic energies below the keV range. The devices in question are back-side-illuminated silicon CCDs with p^+ delta (δ) doping at their back-side interfaces between silicon and surface layers of silicon dioxide. Such a device at an earlier stage of development was described in "Growth of δ-Doped Layer on Silicon CCD" (NPO-18688) in the *Laser Tech Briefs* edition of *NASA Tech Briefs*, Vol. 19, No. 2 (February 1995), page 11.

When an energetic charged particle enters a detector, some of its kinetic energy is dissipated in the generation of electron/hole pairs; the problem is to collect and measure the electron/hole charges before the electrons and holes recombine. In the absence of δ doping, the inability of a silicon back-surface-illuminated device to detect either ultraviolet photons or low-energy charged particles is attributable to a "dead" layer that includes the surface SiO_2 plus a potential well that extends about 0.5 μm into the silicon from the Si/SiO_2 interface (see figure). The depth of penetration of the particles in the energy range of interest is less than the depth of the dead layer. Consequently, most of the electrons generated by impingement of charged particles become trapped in the potential well, where they eventually recombine with holes and thus go undetected.

Delta doping reduces the low-energy detection limit by effectively eliminating the back-side potential well. Delta doping is so named because its density-vs.-depth characteristic is reminiscent of the Dirac δ function (impulse function); the dopant is highly concentrated in a very thin layer. Preferably, the dopant is concentrated in one or at most two atomic layers in a crystal plane and therefore δ doping is also known as atomic plane doping.

An experimental δ-doped CCD for detecting low-energy charged particles was made by subjecting a commercial CCD to the following additional fabrication steps: First, an atomically clean silicon back surface was prepared by use of a hydrogen-termination surface-cleaning procedure that involves temperatures no more than about 200 °C. Then residues of the cleaning procedure were outgassed in a vacuum as the temperature of the device was gradually increased to an epitaxial-deposition temperature of 450 °C. A 1-nm-thick layer of silicon doped with boron [an acceptor (p) dopant] to a density of 4×10^{20} atoms/cm^3 was deposited epitaxially on the cleaned back surface. The silicon flux was interrupted briefly to enable the deposition of a δ layer of boron with an areal density of 2×10^{14} atoms/cm^2. The silicon flux was resumed to deposit a 1.5-nm-thick cap layer of silicon. Finally, the cap layer was exposed to steam to form a protective oxide on the back surface.

In experiments, the device was found to detect incident electrons with energies as low as 50 eV. Quantitative analysis was performed for incident electrons in the 200-to-1,000-eV range. The signal monotonically increased with increasing energy of the incident electrons. On the basis of data acquired in the experiments, it has been estimated that eventually, cooled, δ-doped CCDs should be able to detect single electrons with energies as low as 100 eV, at a noise limit of 3 electrons per pixel.



A **Potential Well** forms by trapping of positive charges in the oxide layer on the back side of a thin silicon CCD. The potential well captures electrons generated by impingement of low-energy charged particles from the back. Delta doping eliminates the back-surface potential well, making it possible to collect and measure the generated electrons.

This work was done by Shouleh Nikzad, Michael Hoenk, and Michael Hecht of Caltech; Amy Smith of MIT; and Qiuming Yu of Kansas State University for **NASA's Jet Propulsion Laboratory**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Electronic Components & Circuits category.*

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to

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For More Information Circle No. 522

Delta-Doped CCDs for Measuring Energies of Positive Ions

Kinetic energies as low as 1.25 keV can be measured.

NASA's Jet Propulsion Laboratory, Pasadena, California

Research closely related to that reported in the preceding article has shown that δ-doped charge-coupled devices (CCDs) could be used to detect incident protons and perhaps other positive ions, and to measure the kinetic energies of the ions, down to about 1.25 keV. Prior to the development of δ-doped CCDs, the minimum kinetic energy for detectability of protons by solid-state devices was about 10 keV, for the reasons described in the preceding article.

Heretofore, a typical instrument for detecting low-kinetic-energy charged particles and measuring the particle kinetic energies has comprised a relatively heavy, power-hungry electrostatic- or magnetic-energy analyzer followed by a microchannel-plate detector. In contrast, δ-doped CCDs offer the capability for measuring kinetic energies directly in the detection process, without need for electrostatic or magnetic energy analyzers; this opens up the possibility of developing simpler, smaller, low-power-consumption instruments for measuring low-kinetic-energy charged particles.

An experiment was performed to demonstrate the use of a δ-doped CCD to detect incident protons and measure their kinetic energies. A δ-doped CCD with associated camera electronics was placed in a vacuum chamber, attached to a magnetically analyzed low-kinetic-energy proton-beam apparatus. The responses of the CCD were then measured at proton kinetic energies from 12 down to 1.25 keV. The CCD output signals were found to vary monotonically with proton kinetic energy throughout the energy range of the experiment.

This work was done Shouleh Nikzad, Stythe Elliott, Thomas Cunningham, Walter Proniewicz, D. R. Croley, G. B. Murphy, and Dale Winther of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Electronic Components & Circuits category.*

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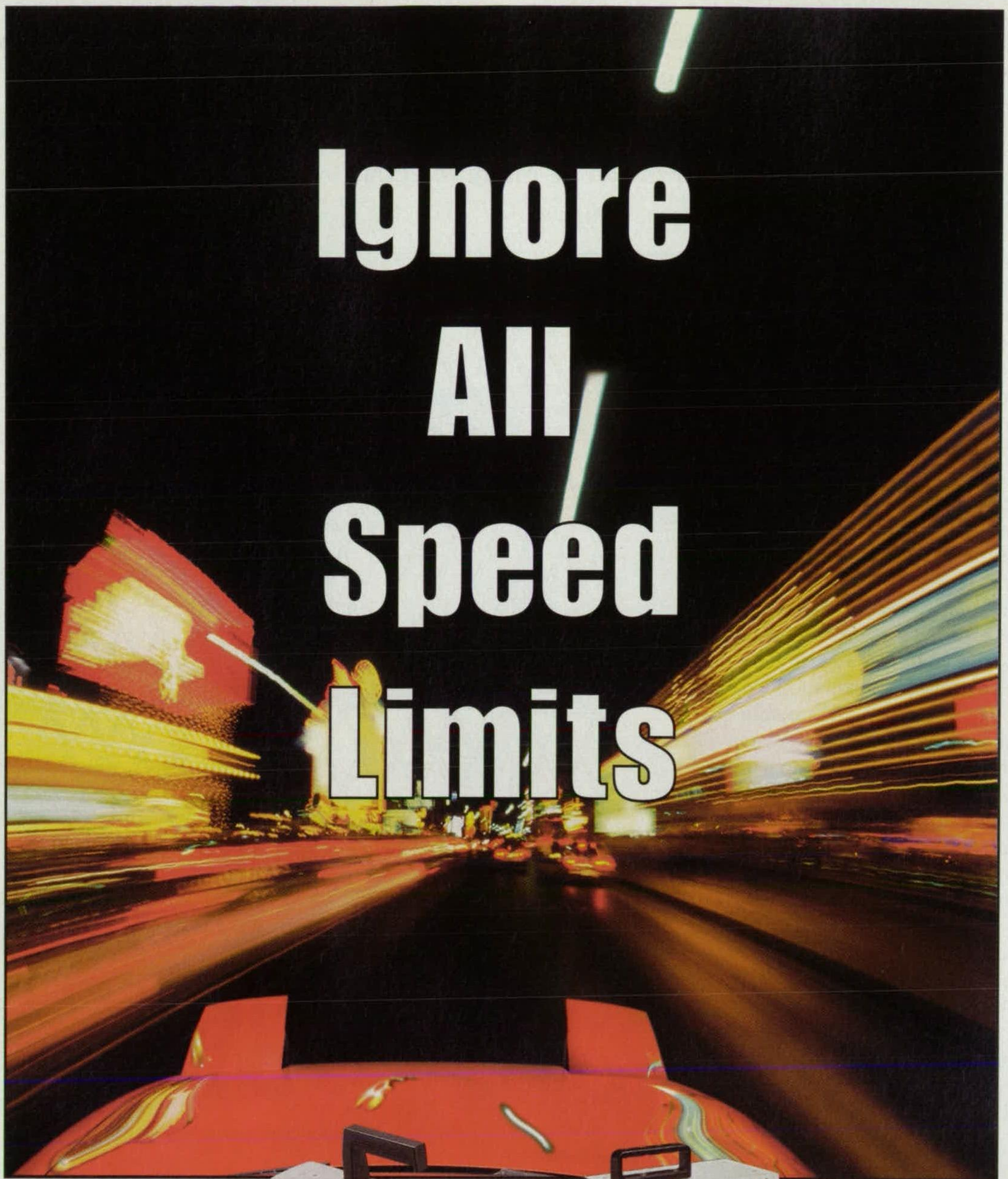

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For More Information Circle No. 511

Inverse Rectennas for Two-Way Wireless Power Transmission

Suitable rectennas under reverse bias can be made to act as transmitters.

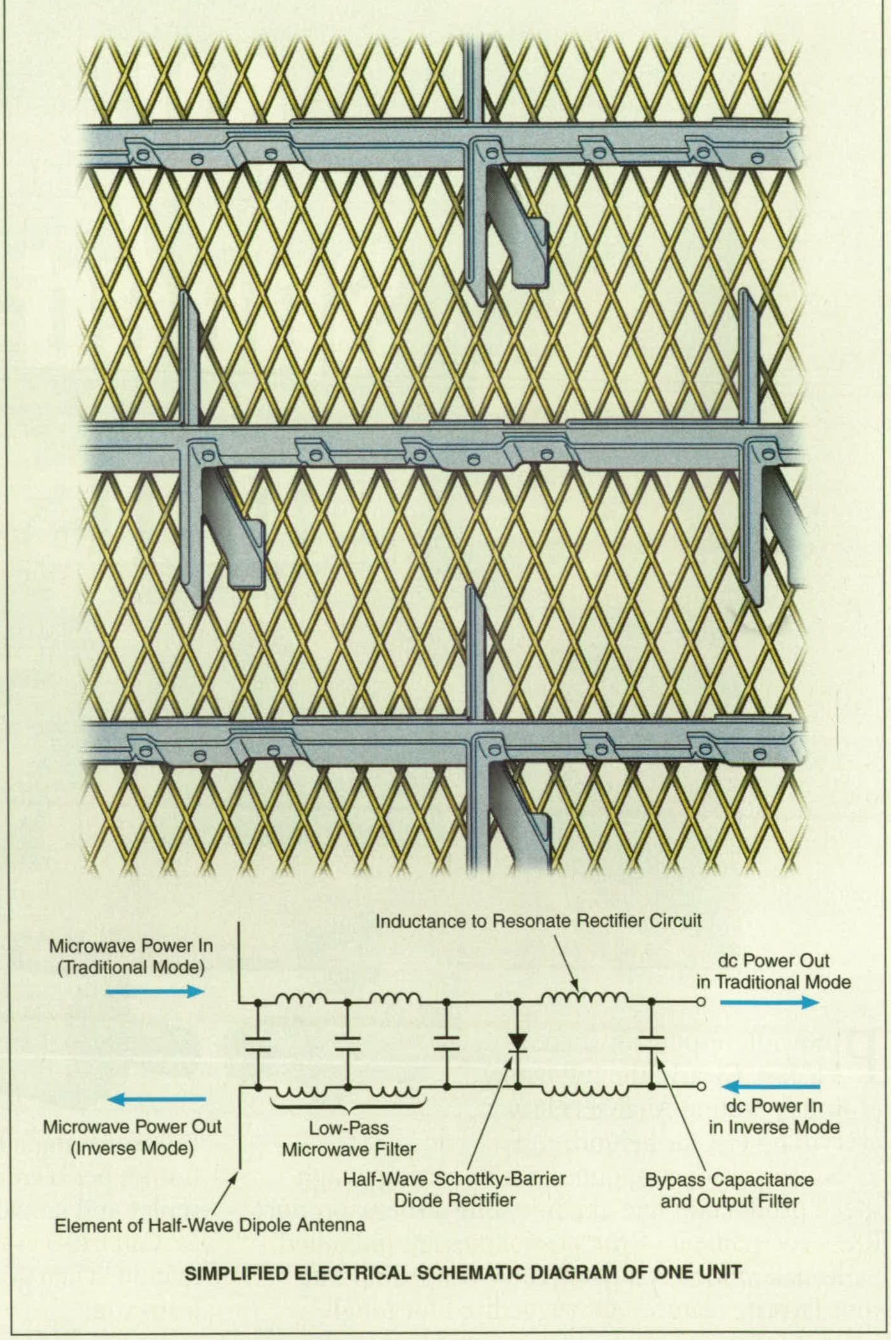
NASA's Jet Propulsion Laboratory, Pasadena, California

The term "inverse rectenna" may seem like an oxymoron at first glance. However, preliminary experiments have demonstrated that a rectenna of suitable design can be made to operate in an inverse mode, in which radio-frequency (RF) power is generated in the rectenna rectifier circuits and radiated by the rectenna antenna elements.

This experimental finding provides encouragement for the use of rectennas as bidirectional (both transmitting and receiving) devices in developmental microwave wireless-power-transmission systems. Heretofore, a bidirectional microwave terminal for a typical conceptual wireless-power-transmission system might have included (a) a transmitter comprising a transmitting antenna connected to a magnetron or klystron oscillator or perhaps an impact avalanche transit-time- (IMPATT)-diode oscillator, plus (b) a receiver comprising a separate rectenna. If only one device — a rectenna capable of operating in transmitting as well as receiving mode — could be used at each end of a microwave power link, then the cost of the link could be reduced. Potential applications for inverse rectennas lie in the microwave wireless transmission of power between any two of the following: ground stations, airships, aircraft, and spacecraft.

In the rectenna used in the experiments, the rectifier circuits included low-pass microwave filters and microwave resonators connected to GaAs Schottky-barrier diodes (see figure). Inverse operation was obtained by doing little more than treating the dc-output terminals as dc-input terminals. By simply applying reverse-polarity dc bias to these terminals, the rectifier circuits were made to function similarly to IMPATT-diode oscillators.

Approximately, 1 percent dc to RF conversion efficiency was obtained, with oscillations at 3.3 GHz. In previous research, rectenna energy-conversion efficiency as high as 91 percent had been achieved in the receiving mode. However, IMPATT oscillators are typically only about 10-percent efficient; in other words, about 90 percent of the dc input power becomes heat, which must be removed. Special provisions for heat sinking were made for the experiments. The issues of energy-conversion efficiency and heat sinking would have to be addressed in developing practical inverse rectennas.



This **Rectenna Array** consists of multiple identical units, each containing dipole microwave antenna elements, microwave circuitry, and a half-wave rectifier in the form of a GaAs Schottky-barrier diode. In the traditional mode of operation, the array acts as a receiver, converting incident RF power to dc power. In the recently discovered inverse mode, the array acts as a transmitter, converting dc power to radiated RF power.

This work was done by Richard M. Dickinson of Caltech and James McSpadden of Texas A&M, NASA Center for Space Power, for **NASA's Jet Propulsion Laboratory**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Electronic Components & Circuits category.* *NPO-20321*

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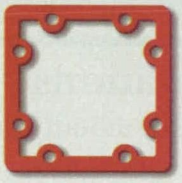
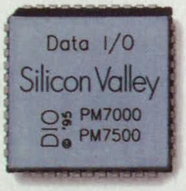


Gasket Manufacturing

Color Marking on Anodized Aluminum

Engraving Wood



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For More Information Write In No. 520

Electronic Systems

Terrestrial Portable Spacecraft-Mission-Support Stations

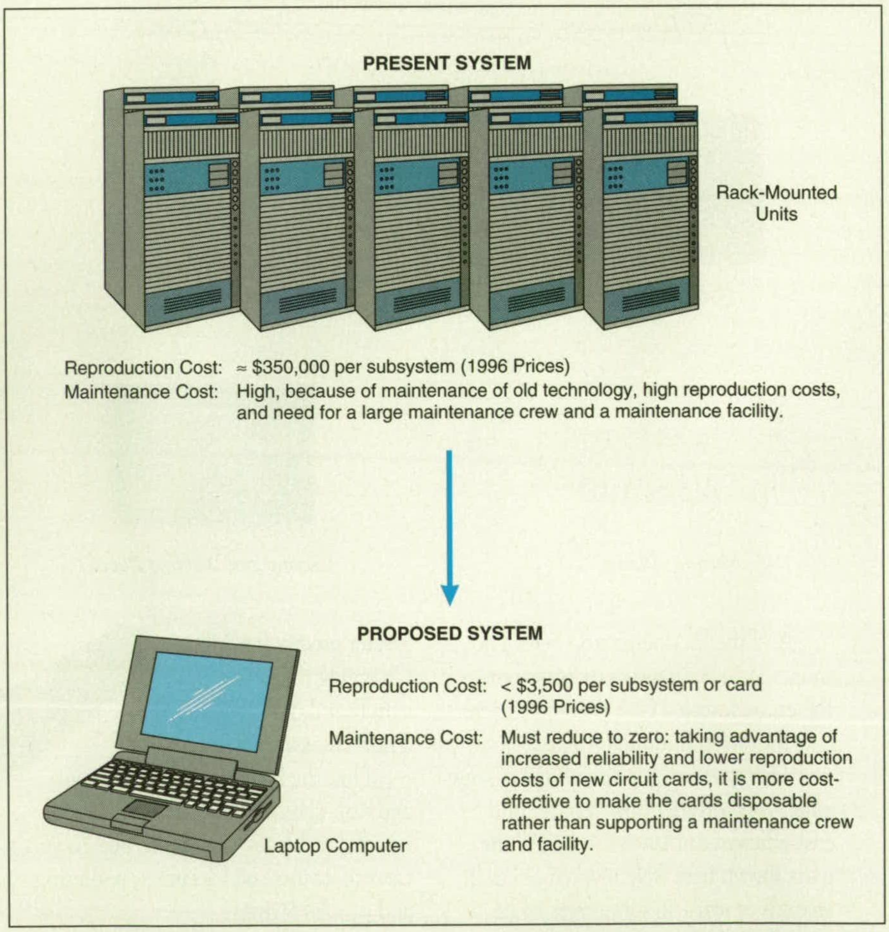
Augmented laptop computers would perform tracking, telemetry, command, monitoring, and control functions.

NASA's Jet Propulsion Laboratory, Pasadena, California

A data-communication and -processing network of compact, laptop-computer-based portable stations communicating via the World Wide Web (WWW) has been proposed as a relatively inexpensive end-to-end ground support system for future spacecraft missions. At present, end-to-end ground support functions (receiving, tracking, telemetry, command, monitoring, and control) are distributed among several subsystems in rack-mounted chassis (see figure). Many of these subsystems have outdated designs that entail high reproduction, maintenance, and operational (labor) costs. The costs are even higher than they might otherwise be because some functions are duplicated by two independent systems at NASA's Jet Propulsion Laboratory: the Deep Space Communications Complex (DSCC) and the Advanced Multi-Mission Operation System (AMMOS). The AMMOS is an intermediate product of evolution toward the proposed system and is not an end-to-end system; in the AMMOS, some telemetric and interfacial functions are implemented in software on a laptop computer, at data rates that are too low for typical spacecraft missions.

In the proposed system, only the antenna subsystems, central command subsystems, receivers, transmitters, and data-storage or -buffering equipment would be retained at the DSCC. The other subsystems and the duplication between the DSCC and the AMMOS would be eliminated. Functions of tracking, ranging, command, monitoring and control, simulation and processing of telemetric data, central processing of data, and operation of the network would be performed by combinations of hardware and software in the portable stations.

To keep costs low, the portable stations would be made of commercial off-the-shelf products to the extent possible. To achieve the required data rates and promote modularity and interoperability, separate subsystem functions (e.g., telemetry, tracking, ranging, and command) would be implemented in hardware on separate circuit cards that conform to the Personal Computer Memory Card International Association (PCMCIA) standard. The sizes of integrated circuits on the PCMCIA cards could be reduced by use of multichip-module (MCM) packaging techniques.



Mission-Support Electronic Systems Are Evolving from assemblies of expensive, obsolescent, rack-mounted units in central locations to cheaper, laptop-computer-based portable units.

A portable station could be operated at any suitable location in the world; for example, at the DSCC, aboard a vessel, at a field site on land, or in a researcher's office or laboratory at a university. The system would enable a scientist to perform multiple tasks simultaneously from such a location. For example, a scientist could perform a sea-floor geodesy experiment by use of the Global Positioning System while tracking a spacecraft and processing telemetric data. Inasmuch as only one operator (the scientist or an assistant) would be able to manage all of these tasks, the cost of operating the system would be less than that of operating the present system, which depends on multiple operators. The innovations discussed here are formulated concepts, and have not been fully reduced to practice.

This work was done by Barbara Lam of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Electronic Systems category. NPO-20286*

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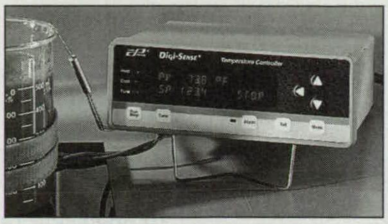

Enable direct plug-in of heating devices; advanced models with free software for remote control

Controllers feature plain English menus and multiple selectable control modes from simple on/off to sophisticated autotuning PID. Safety features include over-temperature and timer cutoffs, separate fuses for instrument and output receptacles, and out-of-range alarms that are both audible and visual.

All models accept eight types of thermocouple probes and permit direct plug-in of heaters and other devices. Advanced models include bidirectional RS-232, free control software, and ramp and soak capabilities for storing up to nine programs.

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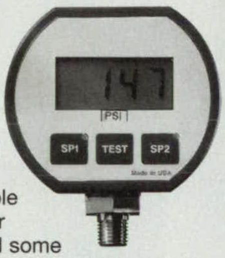

These new pressure gauges feature high accuracy (±0.25%) and 316 stainless steel media capability. Models are available for loop, battery, or AC/DC power; and some have alarm and/or retransmission options. All models feature large, clear 3½-digit display; rugged, aluminum case; and test gauge accuracy. With the variety of configurations, and ranges available, you're sure to find the gauge you need for your pressure application.

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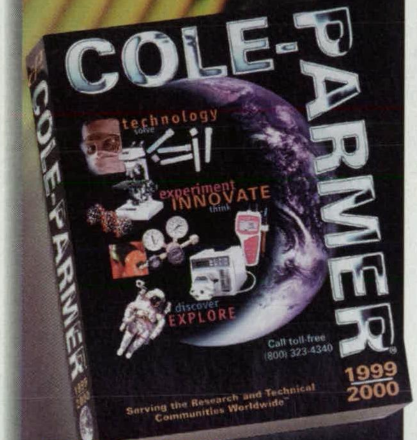

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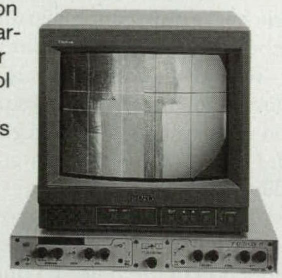
This NTSC/EIA, RS-170 screen splitter accepts input from two cameras for high-resolution image comparison. Ideal for quality control applications. Display inputs side-by-side on the split screen, or see either input full screen.



Create independent single/double crosshairs or size adjustable box reticles for each image.

Screen splitter supplies power to each camera and includes cables. Compatible with color or monochrome video.

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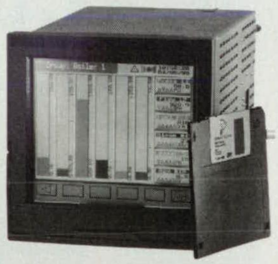
New Multi-Color Graphic Recorders

Touch-screen permits rapid movement between displays

Gain quick access to plant operating conditions with these full-color graphic recorders. The high-resolution LCD and touch-screen technology ensure that all functions are instantly accessible and easy to analyze. Models available with 6 or 12 isolated inputs to monitor thermocouples, RTD, DC voltage, DC current, and ohm readings.



Trend function displays current and historical data for comparison, and a built-in 1.4 MB floppy drive lets you transfer data to your spreadsheet software. Recorders feature four alarms per channel and an IP65 rating for use in hostile environments.

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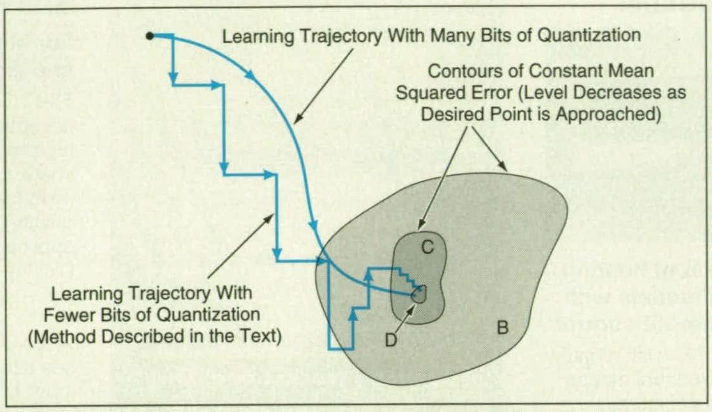
Training Neural Networks With Fewer Quantization Bits

Maximum synaptic weights are progressively reduced in the cascade back-propagation learning algorithm.

NASA's Jet Propulsion Laboratory, Pasadena, California

A method for reducing the number of bits of quantization of synaptic weights during training of an artificial neural network involves the use of the cascade back-propagation learning algorithm. The development of neural networks of adequate synaptic-weight resolution in very-large-scale integrated (VLSI) circuitry poses considerable problems of overall size, power consumption, complexity, and connection density. Reduction of the required number of bits from the present typical value of 12 to a value as low as 5 could thus facilitate and accelerate development.



Learning Trajectories of a neural network are plotted symbolically in a plane, in which the two perpendicular axes represent the many synaptic-connection-weights. During learning according to the method of the text, the size of the steps is reduced when the trajectory reaches the contour at error level B. The size of the steps is further reduced upon reaching error level C. Learning is stopped upon reaching the contour at error level D.

In this algorithm, neurons are added sequentially to a network, and gradient descent is used to permanently fix both the input and output synaptic weights connected to each added neuron before proceeding further. Each added neuron has synaptic connections to the inputs and to the output of every preceding neuron; thus, each added neuron implements a hidden neural layer. The addition of each successive neuron provides an opportunity to further reduce the mean squared error. Because the average number of connections to a neuron is small, learning is quite fast.

To adapt the cascade back-propagation algorithm to neural-network circuitry with limited dynamic range (equivalently, coarse weight resolution) in the synapses, one reduces the maximum synaptic conductances associated with neurons added later. This effectively reduces the sizes of synaptic-weight quantization steps, so that in the later stages, the desired synaptic-weight resolution is ultimately achieved and the learning objective approached as closely

as required, without having to increase the number of bits (see figure).

Both simulations and tests with analog complementary metal oxide/semiconductor (CMOS) VLSI hardware have shown that by use of this method, neural networks can learn such difficult problems as 6-bit parity with synaptic quantizations as low as 5 bits, as opposed to the 8 to 16 bits required in the older error-back-propagation and cascade-correlation neural-network-learning algorithms.

This work was done by Tuan A. Duong of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Electronic Systems category. NPO-19565*

GPS Drives Interactive Map Showing Position of Test Airplane

This system could augment, back up, or substitute for a radar-based system.

Dryden Flight Research Center, Edwards, California

An electronic system that comprises airborne and ground-based subsystems generates data for a global real-time interactive map (GRIM) that displays the current position and velocity of the NASA F-18 Systems Research Aircraft (SRA). This system utilizes the Global Positioning System (GPS) to determine the position and velocity of the aircraft; it serves as a prototype for the development of other, similar GPS-based systems that could be used for tracking and guidance of aircraft during flight research. Such GPS-based systems could be used to augment, back up, or substitute for radar-based tracking systems; indeed, as described below, the performance of the prototype GPS-based system has been compared with that of a radar-based tracking system in initial tests.

Located aboard the SRA, the prototype airborne subsystem includes a GPS receiver (see Figure 1). The output data from the GPS receiver are melded into a stream of telemetry data, which are transmitted from the SRA to a ground station on a pulse-code-modulated radio signal. The ground-based subsystem includes the GRIM display equipment, which resides in a control room at Dryden Flight Research Center. Previously, the GRIM was driven by data from a ground-based FPS-16 radar subsystem. The development of the present system included modification of the GRIM to make it possible to track the position and velocity of the SRA simultaneously by use of both radar and GPS information. The GRIM software was modified to display a triangle to represent the position based on radar data and a circle to represent the position based on GPS data (see Figure 2).

At the time of reporting the information for this article, the performances of

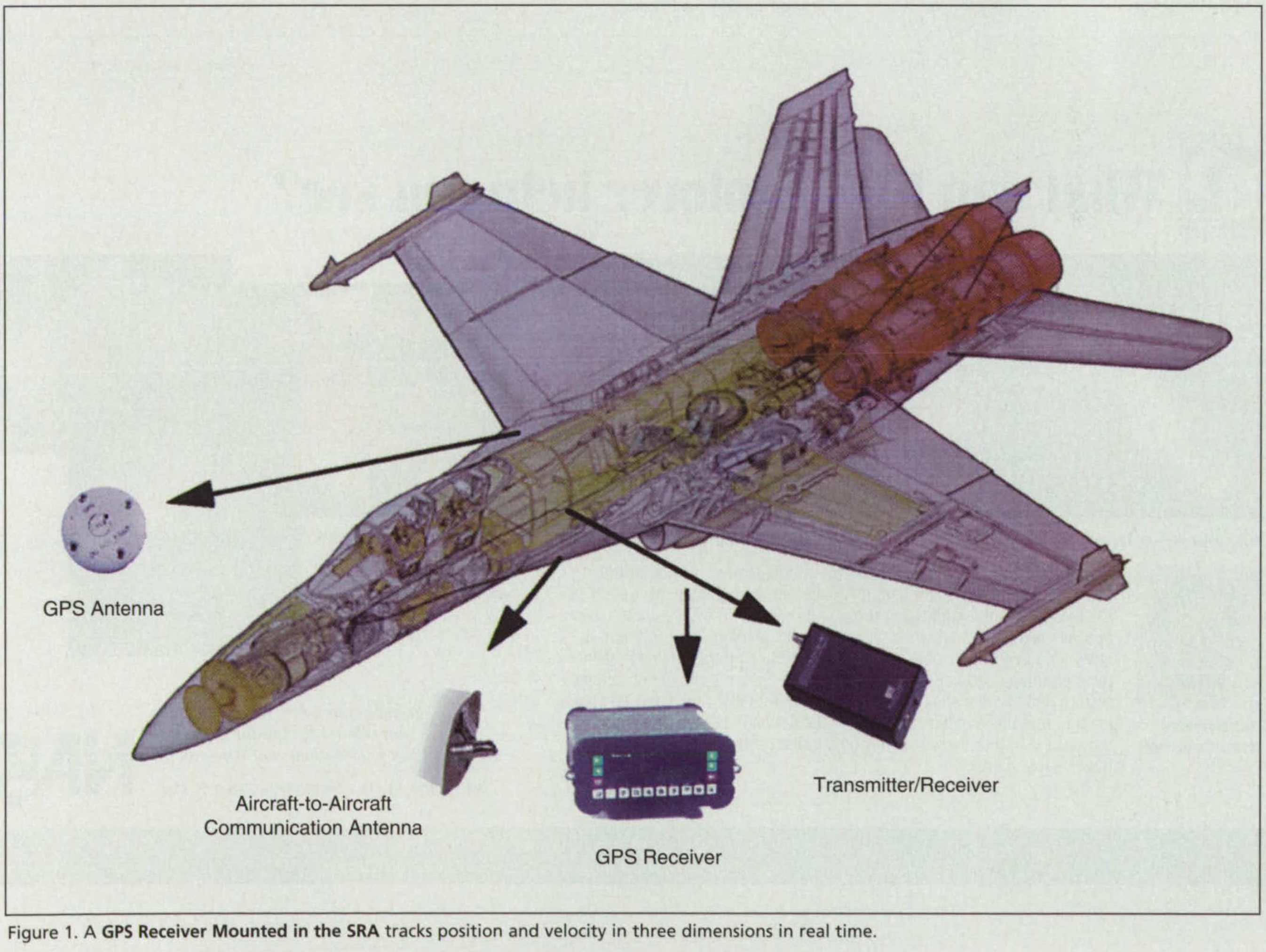


Figure 1. A **GPS Receiver Mounted in the SRA** tracks position and velocity in three dimensions in real time.

the GRIM as driven by GPS and radar-based data had been evaluated and compared in more than ten research flights. Post-flight analysis revealed that GPS data differed from radar data by the following:

Time lag	2 seconds
Horizontal position	GPS horizontal velocity × time lag
Vertical position (see figure)	±300 ft (±91 m)
Velocity	±20 ft/s (±6 m/s)

The system is not limited to a single aircraft. Multiple aircraft can be tracked on the GRIM, using GPS data only, radar data only, or both GPS and radar data. The capability to utilize GPS data is particularly advantageous in situations in which radar resources are insufficient or are unavailable because of competing priorities or schedules.

This work was done by John McGrath; Ed Haering, Jr.; Harry Miller; Jack Trapp; Dave Webber; Glenn Bever; and Joe Collura of **Dryden Flight Research Center;** *Jules Ficke of SPARTA, Inc.; and George Aragon of OAO. For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Electronic Systems category.*
DRC-98-23

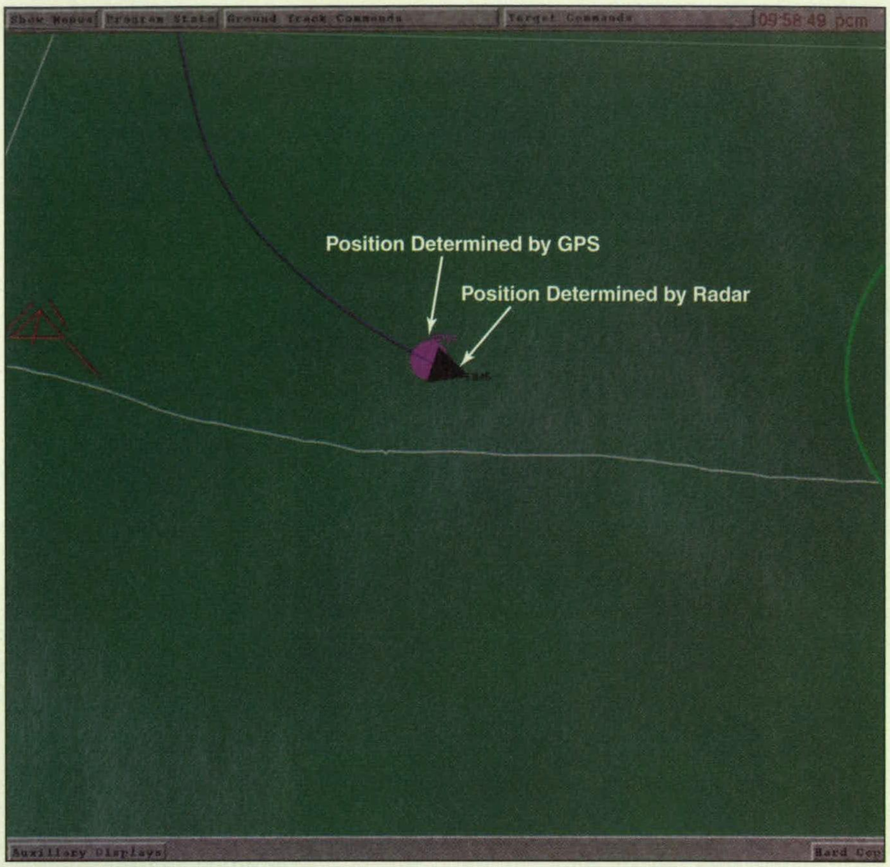


Figure 2. This **GRIM Display,** generated during a test flight, shows ground track and position as determined by GPS and radar.

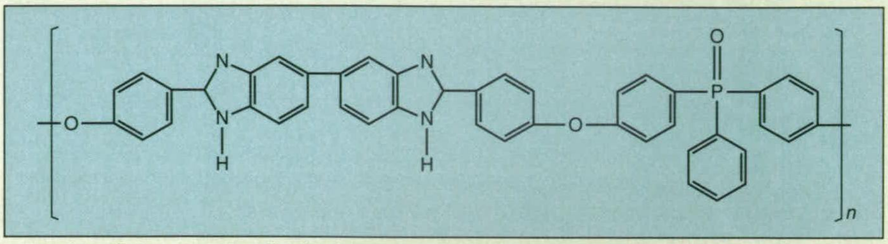
Materials

Matrix and Coating Polymers for Composite LOX Containers

These polymers offer a combination of desirable properties.

Marshall Space Flight Center, Alabama

Two poly(arylene ether phosphine oxide)s (PAEPOs) have been found to be suitable as matrix and coating materials for composite-material (matrix/fiber) tanks and pipes that contain liquid oxygen (LOX). One of these PAEPOs is denoted by the trade name "Triton Oxygen Resistant" (TOR); this is a clear, yellowish material with the structural formula shown in the figure. The other PAEPO is a clear, colorless material called "colorless oxygen resistant" (COR).

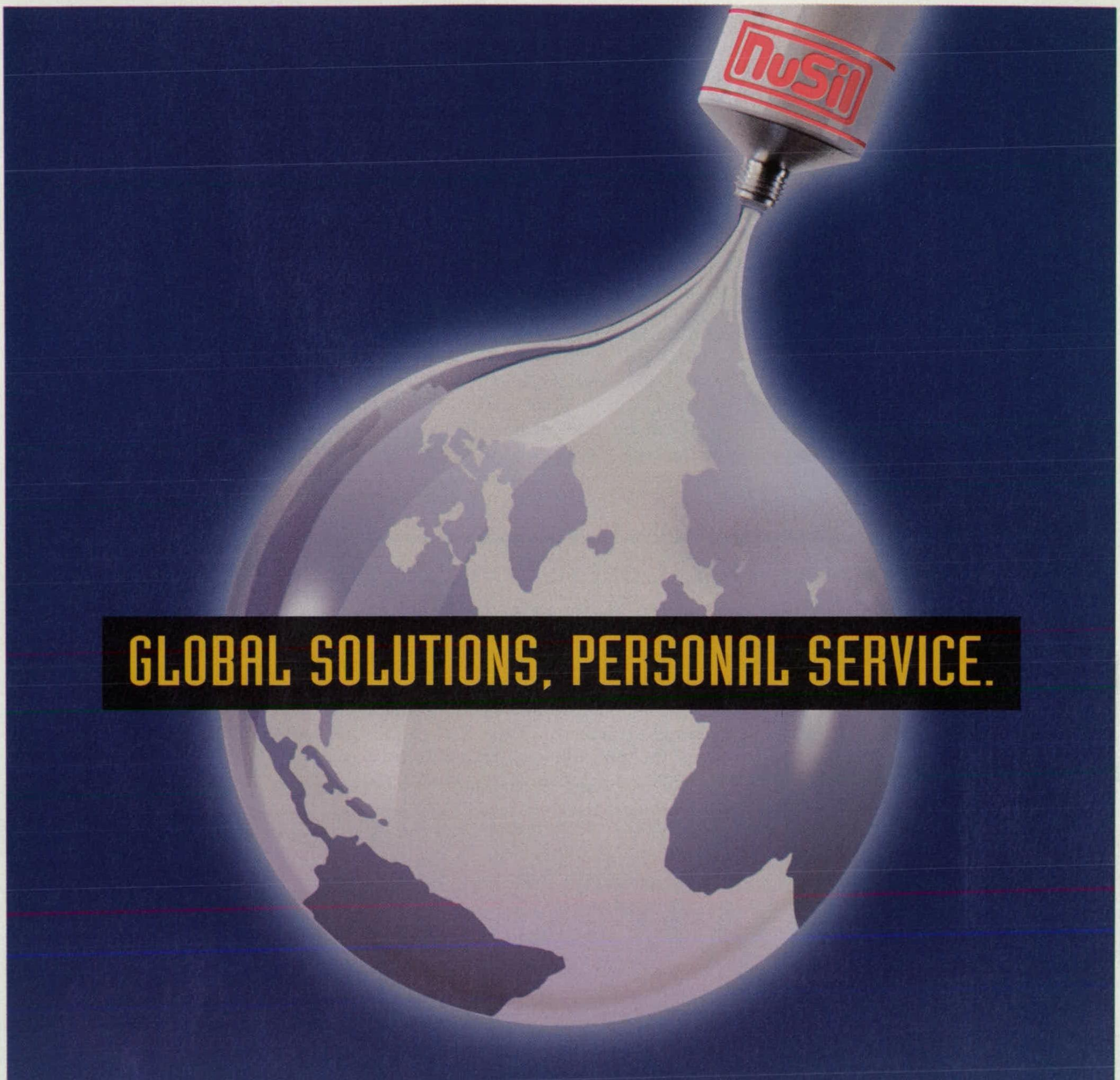


A Member of the PAEPO Family of Polymers, the polymer represented by this structural formula is a clear, yellowish material that is compatible with liquid oxygen.

These polymers exhibit properties that make them attractive for incorporation into composite-material LOX containers:

- They are physically and chemically compatible with LOX.
- They are compatible with the other component materials (toughened epoxies and graphite fibers) of composite-material LOX containers.
- They are amenable to processing by techniques used commonly in the fabrication of composite-material structures.

Some other commercially available polymers are compatible with liquid oxygen, but the use of them is inhibited, variously, by poor adhesion to other component materials, difficulties in processing, and/or the need to process them at temperatures high enough to damage other component materials.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These PAEPOs in film form have been shown to be highly compatible with LOX. The films have passed the Marshall Space Flight Center LOX mechanical-impact-sensitivity test at the maximum required energy level of 72 ft-lb (98 J). The PAEPOs are soluble in a number of polar solvents and can therefore be applied from solution onto complexly shaped surfaces with relative ease; for example, by dip coating or brushing. The PAEPO films can be made very thin if necessary, and they adhere well to composites made of other component materials.

These PAEPOs can also be used as matrix materials, along with graphite-fiber reinforcements, in prepregs and in composites made from prepregs by standard thermoplastic-matrix-composite consolidation techniques: A composite panel can be laid up by stacking multiple prepreg plies; the layup is then vacuum bagged and consolidated in a hot press or autoclave. However, like composites made with other matrix materials, composites made with these polymers fall shy of the neat polymer films in LOX testing. The reason for this behavior and what (if anything) can be done about it will be addressed in subsequent development work.

Although a PAEPO film can be applied to a previously cured epoxy-matrix/graphite fiber structure, the most unique and promising way of coating such a structure with a PAEPO film is to make the film become intimately bonded with the underlying composite by use of the composite cocure process. In this approach, a thin film of the PAEPO is applied on one side of a epoxy/graphite prepreg layup prior to curing. Then as the layup is cured to the finished composite, the film forms a strong bond with the epoxy matrix. This process offers two advantages: (1) it is solventless and (2) it results in an excellent bond.

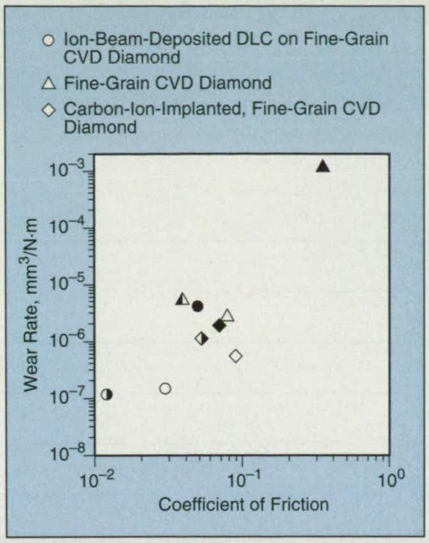
This work was done by Marvin A. Guiles and Ross Haghighat of Triton Systems, Inc., for **Marshall Space Flight Center.** *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Materials category.*
MFS-26541

Ion-Beam-Deposited DLC Coatings on Fine-Grain CVD Diamond

Friction and wear are reduced, relative to as-deposited CVD diamond.

Lewis Research Center, Cleveland, Ohio

Ion-beam-deposited surface layers of diamondlike carbon (DLC) on fine-grain chemical-vapor-deposited (CVD) diamond have been found to be effective in reducing friction and wear in a variety of environments, including ultrahigh vacuum. This discovery opens the possibility of taking fuller advantage of the properties of CVD diamond and DLC to manufacture protective coatings to provide solid lubrication and resistance to wear, erosion,



Wear Rates and Coefficients of Friction were determined in sliding-contact tests. Outline symbols indicate tests in humid air, half-darkened symbols indicate tests in dry nitrogen, and fully darkened symbols indicate tests in vacuum.

and corrosion. Such coatings could be applied to surfaces of bearings, valves, cams, gears, and magnetic recording disks and tapes, for example. Notwithstanding the high costs of natural diamonds of gem quality, the costs of DLC and CVD diamond are similar to those of CVD and physical-vapor-deposited (PVD) carbide and nitride films. The one major disadvantage of DLC is its lack of resistance to high temperature; its use must be restricted to temperatures ≤250 °C in air and ≤350 °C in vacuum.

CVD diamond offers some solid lubrication and resistance to wear. However, friction and wear rates of as-deposited CVD diamond depend on the environment; in particular, they are greater in vacuum than in humid air or dry nitrogen. CVD diamond can be modified by carbon- or nitrogen-ion implantation to obtain an amorphous, nondiamond carbon surface layer that reduces friction and wear regardless of the environment. However, the surface layer is usually ≤0.5 µm thick; consequently, endurance is limited in the sense that use must typically be limited to light-load and/or short-term operations. In contrast, DLC films can be deposited to thicknesses as great as 5 µm, with concomitant potential for increasing endurance.

The wear-reducing and self-lubricating properties of specimens of ion-beam-deposited DLC on fine-grain CVD diamond were investigated in a series of experiments. For comparison, specimens of ion-beam-deposited DLC on silicon and specimens of both as-deposited and carbon-ion-implanted fine-grain CVD were also included in the experiments. The specimens were fabricated on flat disk silicon substrates, then coefficients of friction were measured while the specimens were rotated in sliding contact with CVD-diamond-tipped hemispherical pins.

The sliding-contact tests were performed in humid air, dry nitrogen, and vacuum. Surface profilometry was performed to characterize surface features and determine surface roughnesses and depths of wear. The results of the sliding-contact tests (summarized in the figure) indicate that ion-beam-deposited DLC can effect significant reductions in the friction and wear of fine-grain CVD diamond.

This work was done by Kazuhisa Miyoshi of **Lewis Research Center** *and Richard C. Wu and William C. Lanter of K Systems Corp. For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Materials category.*

Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Lewis Research Center, Commercial Technology Office, Attn: Tech Brief Patent Status, Mail Stop 7–3, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-16564.

Vol. 22, No. 7 July 1998 This form expires: December 31, 1998

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July 1998

Electronics TECH BRIEFS

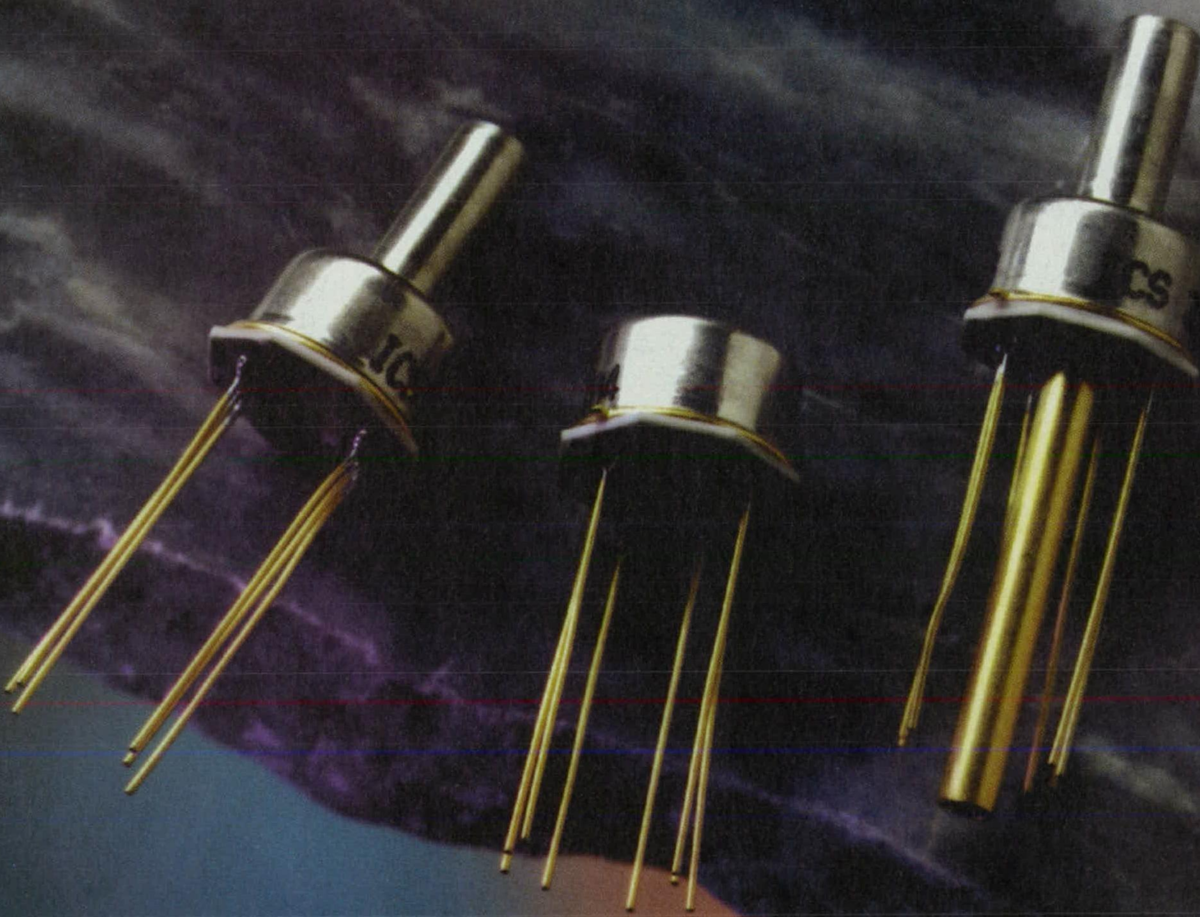

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Photo courtesy EG&G IC Sensors—see New Products

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NEWS BRIEFS

Notes from Industry and the Federal Laboratories

The first annual ***Electronics Tech Briefs*** Product of the Year Award for 1997 was won by **MicroSim Corp.**, of Irvine, CA, for its Release 8, a tightly integrated start-to-finish desktop electronic design automation (EDA) system for mixed analog/digital designs. The company (which merged late last year with **OrCAD**, of Beaverton, OR) points to two new features as innovative: Design Journal™ and Design Manager. The first enables engineers to mark checkpoints at key crossroads, try alternative design directions, compare the results of all the alternative choices on a single graph, then proceed with the best option. Design Manager functions as an automatic organizer, linking together all files, even non-EDA documents and references to outside definitions, associated with the design into a single, self-contained entity. Symbols from Models, another key feature, allows engineers to download simulation models published by manufacturers on the Internet, and the system will create symbols for the models automatically in minutes.

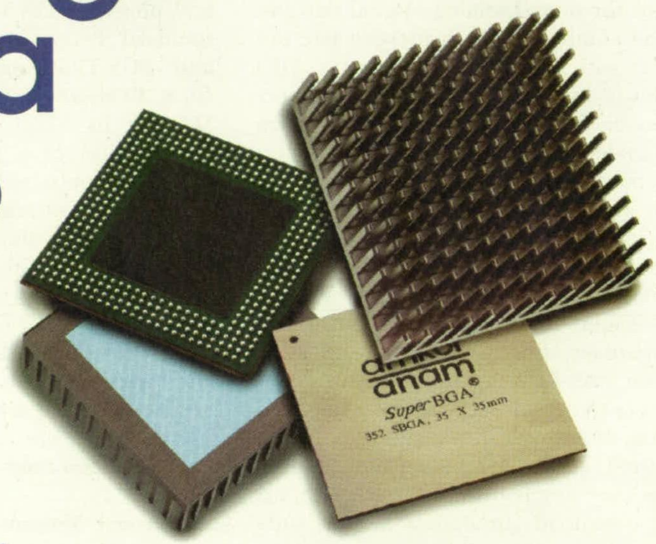
Other finalists were **GenRad Inc.** of Concord, MA, for the Viper Visual Inspection System, designed to provide a cost-effective solution for detecting and preventing defects in the component-placement process for printed circuit boards; **Cognex** of Natick, MA, for the 8000 Series™ machine vision platform that incorporates its PatMax™ software and plugs directly into the PCI bus of standard Pentium MMX™ computers; and **SGS-Thomson Microelectronics** (now **STMicroelectronics**) of Lincoln, MA, for its VIPer 100, a monolithic combination of a state-of-the-art current-mode pulse width modulation circuit and an optimized avalanche energy-rated high-voltage vertical power MOSFET. Each of the contending products had been a Product of the Month in 1997, chosen by *Electronics Tech Briefs'* editors for outstanding technical merit and practical value to the magazine's engineering and management readers. The winner was chosen by ballot by *Electronics Tech Briefs'* readers.

Schroder Ventures, an international group of investors with offices in London and Frankfurt, agreed to acquire **Leica Microsystems Group** of Wetzlar, Germany, from **Leica Holdings B.V.** of Rijswijk, the Netherlands. Concurrently, Leica Microsystems announced that it had acquired the assets and employees of **Jenoptik Silmetric GmbH** of Jena, Germany, formerly part of the Jenoptik complex, and renamed it **Leica Microsystems Jena GmbH**.

In March of 1996, Leica acquired the business unit Electron Beam Lithography Systems from Jenoptik, and dubbed it Leica Microsystems Lithography GmbH. Leica Microsystems is a worldwide presence in each of its five business areas: microscopy, preparation of microscopic specimens, image analysis and laser scanning microscopy, medical technology, and equipment for the semiconductor industry. Jenoptik Silmetric was active in the market for automated optical inspection and measuring technology for the semiconductor manufacturing industry. The acquisition will bring Leica Microsystems Jena's employee count to 94.

With a worldwide network of 18 sales companies, 11 factories in seven countries, and a total workforce of 3600 employees, Leica Microsystems has annual revenues of more than 880 million Deutschmarks ($500 million).

A Thermal Challenge Meets a Unique Design



Aavid's OptiPin heat sinks for Super BGA packages utilize an optimum fin geometry to get the maximum amount of cooling out of a low-air-flow environment. This design uses pin-shaped fins, with pin size versus pin spacing specifically designed for air flow of 150 lfm or less.

Today's electronic components are increasingly demanding of thermal solutions to remove excess heat. Heat dissipation is necessary not only to prevent failure of devices but also to increase the devices' reliability. Finding the correct solutions to such challenges is becoming more difficult as electronic devices decrease in package size and increase in power. The problem becomes worse with geometries that allow little or no air flow. Not only must the thermal requirements be met; the solution must accommodate constraints on heat-sink size. Because board real estate is at a premium, this poses a formidable challenge. When choosing a heat sink, the design engineer must consider whether it can dissipate the required amount of heat yet still fit within the available space.

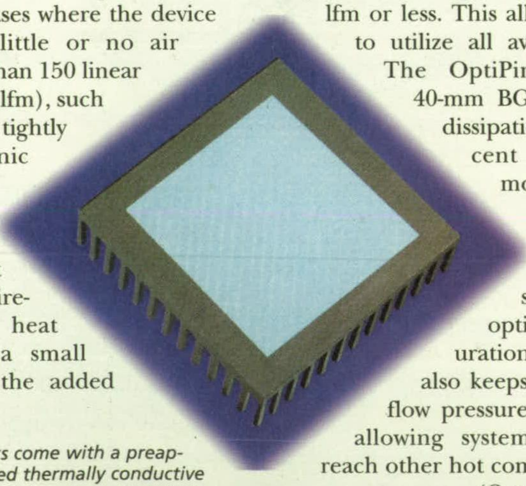
AAVID'S new heat sink optimizes cooling of ball grid arrays.

A Tight Squeeze

Nowhere is the space requirement more stringent than in today's PC boards. With board densities increasing, the requirement for smaller heat sinks becomes apparent. This is especially true in the world of ball grid array (BGA) packaging, where devices that previously did not require a demanding thermal solution now present significant design challenges.

Increasingly popular, BGAs are found in applications such as high-speed network routers, automotive global positioning systems, and high-resolution plotters. One example of a BGA that presents difficult thermal hurdles is a 40-mm BGA-packaged microprocessor with a power dissipation requirement of about 8 W. In cases where the device is exposed to little or no air flow — *i.e.*, less than 150 linear feet per minute (lfm), such as in small and tightly packed electronic packages, a unique heat sink is called for. It must meet the typical requirements of high heat dissipation in a small envelope, with the added constraint of low air flow. The new OptiPin heat sink from Aavid Thermal Products meets all these requirements.

The OptiPin is only 1.58 in. square and 0.45 in. high, and weighs 14.6 grams. Proprietary thermal modeling programs helped identify the optimum fin geometry to get the maximum amount of cooling in an environment of low air flow. This design uses pin-shaped fins, with pin size versus pin spacing specifically designed for air flow of 150 lfm or less. This allows the OptiPin to utilize all available air flow. The OptiPin can keep a 40-mm BGA chip, at 8 W dissipation, 10 to 20 percent cooler and, in most cases, occupy less space than conventional heat-sink designs. The fully optimized fin configuration of the OptiPin also keeps the drop in airflow pressure to a minimum, allowing system-cooling air to reach other hot components.

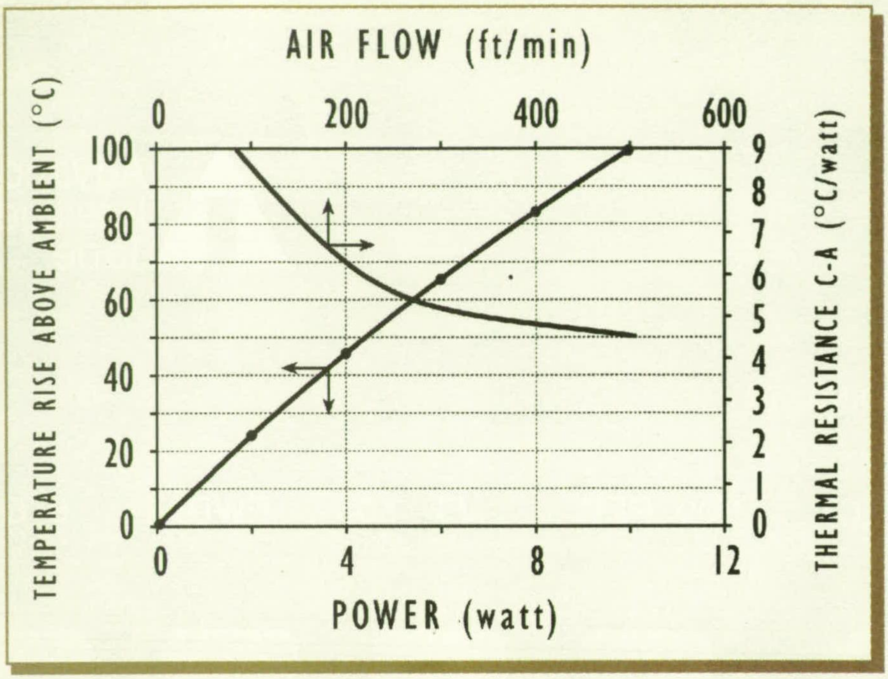


OptiPin heat sinks come with a preapplied double-sided thermally conductive tape for quick and easy installation.

(Continued on page 4a)

Clipping Penalty

The elimination of the socket in surface-mount assembly of BGA packages prevents the convenient use of a clip to attach the heat sink to the device. This limits the choice of attachment methods to drilling holes in the board for mechanical attachment, or using adhesives to mount the heat sink directly to the BGA. Lack of board real estate may prohibit using holes in the board. OptiPin answers the attachment question by offering thermally conductive double-sided preapplied tape. This is a peel-and-stick tape, enabling easy attachment of the heat sink at the production-floor site. OptiPin is also available with a bare mounting surface for use with other thermal adhesives and attachment methods. OptiPin heat sinks are complex extrusions, cross-cut using high-end, high-volume machines to achieve the extremely thin (0.4 mm) pin fins—a manufacturing technique made possible by Aavid's innovative tooling expertise. As a result of this high-yield manufacturing process, OptiPin heat sinks provide customers with a high-volume and thus low-cost thermal solution.



The thermal performance curve illustrates forced vs. natural convection for an OptiPin heat sink.

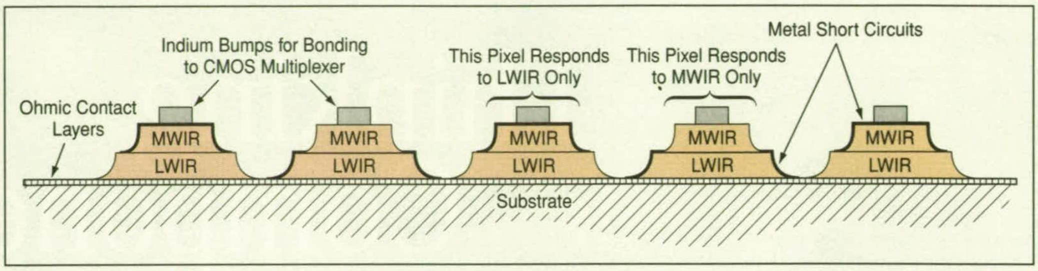
The OptiPin heat sink can be used on other 40-mm-square package types besides BGAs. OptiPin is is suitable for devices such as quad flat packs, plastic lead chip carriers, pin grin arrays, and plastic grid arrays. With a versatility that covers many different types of packages, and fully optimized thermal characteristics, OptiPin is an excellent drop-in solution for board-level heat dissipation applications.

For more information, contact Erik Fleming, Application Engineer, at Aavid Thermal Products, Santa Ana, CA; (714) 241-4141; fax: (714) 556-5140; E-mail: fleming@aavid.com.

Improved Two-Wavelength Focal-Plane Array of QWIPs

Temperatures of objects imaged on the array could be determined.

NASA's Jet Propulsion Laboratory, Pasadena, California



MWIR and LWIR QWIPs Would Be Short-Circuited in alternate rows so that the array would detect interlaced LWIR and MWIR images. This is a schematic partial cross-sectional view looking along the rows.

A focal-plane array (FPA) of GaAs-based quantum-well infrared photodetectors (QWIPs) that would detect images in two wavelength bands simultaneously is undergoing development. From ratios between image intensities at the two wavelengths, one can calculate the temperatures of imaged objects by use of Planck's radiation law. In several respects, this device is similar to the one described in "Two-Wavelength Focal-Plane Array of QWIPs" (NPO-19658) *NASA Tech Briefs*, Vol. 22, No. 1 (January 1998), page 8a. Both devices are intended to serve as prototypes of multispectral imaging devices for a variety of scientific, industrial, and military infrared instruments.

QWIPs that operate in medium-wave infrared (MWIR) and long-wavelength infrared (LWIR) bands have been undergoing development in recent years. The best previously available two-wavelength QWIP contains two stacked, voltage-tunable QWIP structures — one for MWIR and one for LWIR. Two difficulties arise in connection with attempts to utilize that device in an FPA: (1) the device must be supplied with two voltages, which cannot be obtained from any currently available readout multiplexers; and (2) a high bias (>8V) must be supplied to the LWIR segment to switch on LWIR detection.

The present device is designed to overcome these difficulties. It is based partly on the QWIP FPA in a portable camera developed recently by the same innovators. The array would contain 512 × 484 pixels. Each pixel would contain 25 periods of an MWIR QWIP structure stacked with 25 periods of an LWIR QWIP structure. The two stacks would be separated by a heavily doped intermediate GaAs contact layer. The responses of the MWIR and LWIR QWIP structures would peak at wavelengths of 4.5 and 9 µm, respectively. This entire stack as described thus far would be sandwiched between doped GaAs contact layers and grown on a semi-insulated GaAs substrate by molecular-beam epitaxy. A GaAs cap layer would be added on top of a thin AlGaAs stop-etch layer on top of the device to fabricate a light-coupling optical cavity.

All pixels would contain both the MWIR and LWIR structures. However, during a metallization sequence that would be part of the fabrication process, the MWIR QWIPs on odd-numbered rows and the LWIR QWIPs on even-numbered rows of the FPA would be short-circuited (see figure). This interlaced short-circuiting of the MWIR and LWIR detectors would eliminate complicated voltage tuning and the necessity for very high bias voltage to operate the LWIR QWIPS. The QWIP FPA would be hybridized to a 512 × 484 complementary metal oxide/semiconductor (CMOS) multiplexer, which would read the alternating LWIR and MWIR rows to produce both an MWIR and an LWIR image of the same scene.

This work was done by Sarath D. Gunapala of Caltech and Kwong Kit Choi of the U.S. Army Research Laboratory for **NASA's Jet Propulsion Laboratory.** *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Electronic Components and Circuits category.*

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to

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Refer to NPO-19837, volume and number of this NASA Tech Briefs *issue, and the page number.*

Heat Pipes for Temperature Control in Electronics

A 3-mm-diameter heat pipe keeps computer chips from blowing their cool.

Thermacore Inc., Lancaster, Pennsylvania

As electronic circuits become more densely packaged and higher in power, maintaining them within permissible temperature ranges becomes a major issue. This is especially true in the case of such portable devices as laptop computers, cellular telephones, and other handheld units. Cooling by a conventional approach (for example, by use of a fan and a heat sink) ultimately reduces the useful battery power and the useful operating time of a portable device. Using its own funds, Thermacore Inc. employed knowledge gained from the Small Business Innovation Research (SBIR) program to develop a miniature high-performance heat pipe for use in cooling portable electronic devices.

A heat pipe is a sealed heat-transfer element. It makes use of two-phase heat transfer to carry heat at a small temperature drop from an input area, where a working fluid is evaporated, to an output area where the vapor is condensed, giving up its heat of vaporization. Capillary pumping in a porous wick structure returns the condensed liquid to be re-evaporated, thus making the heat pipe passive in the sense that no external power is needed for its operation.

In a laptop computer, a 3-mm-diameter heat pipe (see Figure 1) is used to spread the heat over a large area that is effectively cooled by natural convection. The ability of the 3-mm heat pipe to adequately transport the excess heat is due

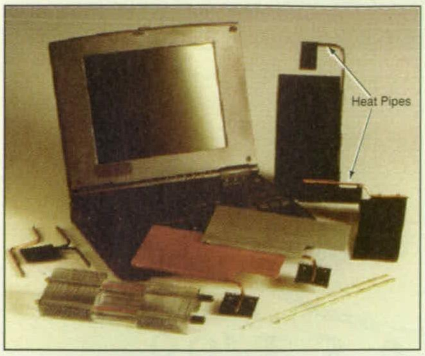


Figure 1. **Heat Pipes in Laptop Computers** help dissipate harmful concentrations of heat.

to a high-performance sintered powder metal wick structure that lines the interior wall. This wick structure also enables the heat pipe to work in any orientation. The heat-pipe pressure boundary and wick are made from copper, and water is the working fluid.

Given the high volume of computer manufacturing, the cost of heat pipes has been reduced significantly, quite often providing economical solutions to problems of cooling in many applications. Thermacore has used company funds to develop the fabrication process needed and to build the factory required for mass production of miniature heat pipes. Production rates have already exceeded 7,500 units per day.

The commercial success of the miniature heat pipes is spawning other advanced heat-pipe-based products. One such product entering the marketplace is the loop heat pipe (LHP) shown in Figure 2. The LHP includes a pair of narrow tubes (typically 3 mm in diameter), several meters long, along which heat can be transported while the tubes are in any orientation. The key to the performance of the LHP is the a small-pore (≤1 μm) powder metal wick structure in the evaporator section. This wick structure is typically made from nickel or stainless steel. The exterior pressure boundary material of an LHP is made of stainless steel or aluminum.

LHPs were invented in the former Soviet Union in the early 1980s. Expertise in the design and fabrication of LHPs was brought to the United States by Thermacore Inc. in 1990. During the past several years, the ability to fabricate all aspects of LHPs was transferred to Thermacore Inc. and its sister company, Dynatherm Corp. This transfer created a United States supplier of LHPs and of expertise pertaining to LHPs.

A family of these devices has been produced to begin to address several applications, such as cooling of avionics in aircraft and missiles, aircraft anti-icing, regulation of temperatures in spacecraft, and solar heating to produce domestic hot water. Development of an LHP anti-icing system is being funded through the NASA SBIR program and monitored by NASA Lewis Research Center. LHPs will be used to passively transport engine waste heat forward to supply heat to critical surfaces to prevent ice formation. Because waste heat is used here, there is no power penalty and engine efficiency remains high. It is anticipated that an operational system will be demonstrated on an unmanned aircraft in late 1998.

Loop heat pipes are also finding their way into applications on spacecraft. Dynatherm Corp. manufactures loop heat pipes for use on satellites. An American-made loop heat pipe was shown to operate successfully during a microgravitational flight experiment aboard the space shuttle (flight STS-87). Further advancements in LHPs are being funded by NASA Goddard Space Flight Center through the SBIR program.

LHPs are expected to be incorporated into rooftop heating units for producing domestic hot water. An LHP can accept solar energy on a roof and transport it passively to a water heater in the basement. Since the LHP subsystem of the hot-water system operates completely

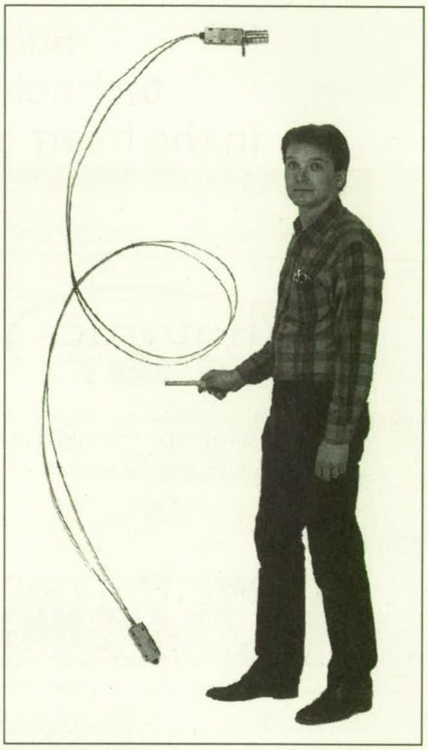


Figure 2. This **4-Meter LHP** delivered thermal power of 225 W against a 9-ft (2.7-m) adverse change in elevation.

passively, an increase in system efficiency over that achieved without solar/LHP augmentation is anticipated.

This work was done by **Thermacore Inc.** *under NASA SBIR contracts monitored by* **NASA's Johnson Space Center, Goddard Space Flight Center,** *and* **Lewis Research Center.** *For more information, contact Nelson J. Gernert: telephone: (717) 569-6551; e-mail address: gernert@thermacore.com; Thermacore Inc., 780 Eden Road, Lancaster, PA 17601.*

Single-Event Latchup Protection of Integrated Circuits

A new technology shows much promise in recovering from single-event upsets.

Space Electronics Inc., San Diego, California

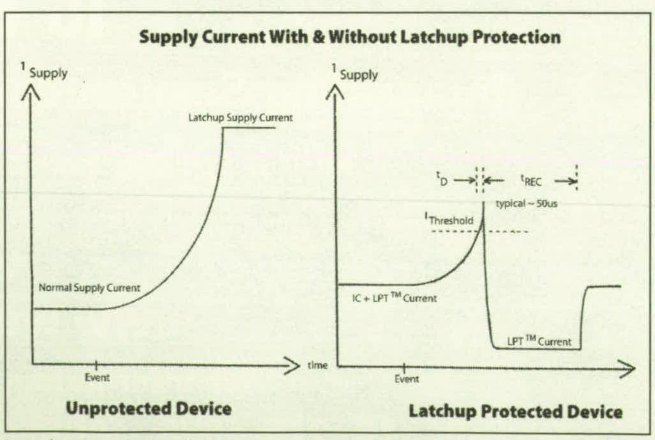
Many commercially available advanced-technology CMOS and bipolar integrated circuits are susceptible to single-event latchup (SEL) effects caused by heavy ions or protons from cosmic rays or solar flares, making them unsuitable for satellite applications. Remanufacturing the integrated circuits in an inherently SEL-immune process has been an expensive and technically difficult option, as is the alternate option of incorporating latchup protection and recovery circuitry in the spacecraft system's electronics.

Space Electronics Inc. has developed several different circuits that provide protection and recovery of integrated circuits known to exhibit single-event-induced latchup. These circuits are integrated within the same package as the susceptible integrated circuit using multichip module (MCM) and modern packaging technology, resulting in a device-level solution providing minimum cost and minimum impact on the system.

The Latchup Protection Technology (LPT™) circuit was designed to provide current limiting to the device, detect the increase in current during the SEL event above a preset threshold, force a shutdown when the threshold is exceeded, hold the device in the shutdown mode for a preset time interval, and return the device's supply voltage to its original operating level.

The LPT circuitry (patent pending) has the potential to be applied to a wide variety of susceptible devices. The specific implementation details such as current latchup protection threshold and supply off time are determined by characterization of the susceptible devices at a heavy ion facility. The LPT device converts a single-event latchup into a recoverable event.

Two devices were evaluated with LPT: the ADS7805 16-bit analog-to-digital converter and the Gatefield GR10009 9000-gate flash programmable gate array. The first was selected for



Supply current waveforms.

latchup protection, and the preliminary circuit design and analysis was based on protecting the ADS7805 device, which is susceptible to SEL at low linear energy transfer levels.

The ADS7805 integrated circuit draws current from an analog and digital supply pin. The LPT circuit must sense the current into the supply pins, and, when the latchup current threshold is exceeded, remove the supply voltage from the latched device. During the time that the supply voltage is removed from the device, the supply current draw will come exclusively from the LPT circuit. After a set time interval required for the latchup to clear, the LPT circuit reapplies the supply voltage to the device and normal operation is restored.

The figure shows the supply current with and without a protection circuit during a single-event latchup. The LPT circuit will have a latchup current threshold, $I_{threshold}$, an activation delay time, t_D, and recovery time t_{REC}. The LPT circuit is activated when the supply current exceeds the $I_{threshold}$ value; the supply current is turned off (grounded) within time t_D after $I_{threshold}$ is reached. The device is off for time period t_{REC}. This can be compared with the unprotected latchup supply current response shown in the figure, where the normal operating current rises to the latchup current in response to a single-event latchup.

Heavy ion characterization and validation of the ADS7805 with the LPT circuitry was performed using the Jet Propulsion Laboratories Californium-252 source at Pasadena, CA, and also using the Texas A&M University cyclotron facility. Latchup protection and recovery of the ADS7805 was demonstrated at both. Peak latchup current was measured between 146 and 267 mA and device recovery as shown with supply off times of 45 µs and 2.5 ms. Additional validation testing was performed by NASA Goddard Space Flight Center.

This work was done by P.J. Layton, D.R. Czalkowski, J.C. Marshall, H.F.D. Anthony, and R.W. Boss at **Space Electronics Inc.**, *4031 Sorrento Valley Blvd., San Diego, CA 92121; (619) 452-4167. RAD-PAK is a registered trademark of Space Electronics Inc. LPT is a trademark of Space Electronics. This work was partially supported by NASA contract no. NAS8-97186.*

SQUID-Based Asymmetric Planar Gradiometer

Reduction of the level of ambient magnetic field noise from distant sources makes possible detection of tiny local magnetic fields.

Ernest Orlando Lawrence Berkeley Laboratory, Berkeley, California

Berkeley Laboratory researchers have demonstrated a novel superconducting gradiometer that helps to reduce ambient magnetic field noise generated by relatively distant sources in favor of tiny magnetic signals generated by a local source. This is another step toward the operation of SQUID-based instruments in an unshielded environment: for example, for the detection of magnetic signals produced by the human heart or brain.

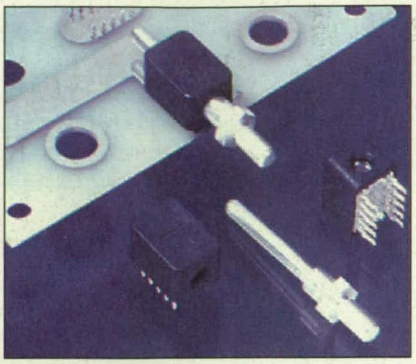
The asymmetric gradiometer consists of a thin film of $YBa_2Cu_3O_{7-x}$ (YBCO) patterned to form two interconnected loops, one much bigger than the other. The smaller loop is inductively coupled to a high-transition-temperature (high-TC) magnetometer. The dimensions of the gradiometer are carefully chosen so that a uniform magnetic field induces no response from the magnetometer. On the other hand, application of a magnetic field that varies spatially along the length of the gradiometer produces a response that is proportional to the gradient. Tests show that uniform magnetic fields in any direction are reduced by at least a factor of 1000. The device involves a single layer of YBCO, and should be relatively inexpensive to manufacture, even with baselines sufficiently long for medical applications.

The most likely applications are in biomagnetism: for example, magnetocardiology and magnetoencephalography. Other potential applications are in nondestructive evaluation of materials.

This work was done by John Clarke and colleagues at **Ernest Orlando Lawrence Berkeley National Laboratory**. *Patents are pending on this invention. Berkeley Lab seeks partners for licensing and/or collaborative development and commercialization of this new technology. For further information, contact Steve Hunter, Technology Transfer Department, Berkeley National Laboratory, 1 Cyclotron Rd., MS 90-1070, Berkeley, CA 94720; (510) 486-5366; fax: (510) 486-6457; TTD@lbl.gov; http://www.lbl.gov/Tech Transfer.*

NEW PRODUCTS

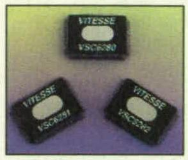
PRODUCT OF THE MONTH



Right-Angle Power Tap Unit

AMP Inc., Harrisburg, PA, offers the Right-Angle Power Tap Receptacle and Power Pin to provide high-current capacity for perpendicular board-to-board and board-to-bus applications. The Power Tap provides power distribution up to 35 A for applications such as networking, mass storage, and base stations. The receptacle is designed with ACTION PIN™ contacts in a 10-pin 0.100-in. by 0.300-in. DIP footprint for industry-standard mounting. The Tap can accommodate board thicknesses from 0.054 to 0.125 in. The installed receptacle mates with a 0.141-in.-diameter power pin that is mounted to either a printed circuit board or a bus bar.

For More Information Circle No. 765



125-MHz Deskew ICs

Vitesse Semiconductor Corp., Camarillo, CA, introduces the VSC6280, VSC6281, and VSC6282, a family of 125-MHz deskew integrated circuits. These digital deskew ICs adjust the delay of eight signals independently over a range of 6 ns with 6-ps resolution for signals up to 125 MHz. They can compensate for path-length differences in shared-resource automatic test equipment systems, such as memory testers, low-cost logic or mixed-signal testers, and burn-in testers. Speed and reliability of datacom backplane systems, computer systems, and telecom central-office equipment are improved by correcting clock and data skew, thus maintaining optimum setup and hold times, Vitesse says.

For More Information Circle No. 766

Control and Data Acquisition System

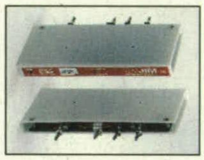
The CellSystem CM/3i from Digalog Corp., Ventura, CA, is a completely integrated system with modular control room and test-cell components that connect with supplied cables to form a complete system for test-cell data acquisition and direct engine/dynamometer control. The real-time control and instrumentation CPU consists of a Pentium PC motherboard MCPU, Ethernet 10/100bT workstation communications link, and Digalog's 16-bit-accuracy continuous autocalibrating analog I/O CPU, digital I/O controller, and ISA-to-Multibus adapter board.

For More Information Circle No. 767

Piezoresistive Pressure Sensors

The TO-8 Series of pressure sensors from EG&G IC Sensors, Milpitas, CA, includes four basic printed-circuit-board-mountable package types. The Models 16/17/46/47, measuring absolute and gauge pressures, are top-entry packages with the pressure port operating away from the PCB. The Models 26/27 are bottom-entry and measure gauge pressures. The Models 36/37 measure differential pressure in a dual-port design that utilizes a combination of both the top- and bottom-entry packages. They are available in 6- and 8-pin packages and in standard ranges from 0-15 psi to 0-250 psi.

For More Information Circle No. 768



Power-Line Surge Suppressor

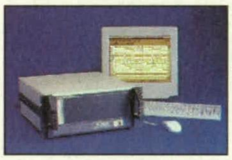
MCG Electronics Inc., Deer Park, NY, introduces the SLIM JIM™, a low-profile AC power-line surge suppressor designed for installation inside a panelboard or cabinet. The units provide up to 6600 J of energy absorption in a 13-in.-×-4.25-in.-×-1-in. package. They are stackable for added protection: one unit has 80 kA capability, two 160 kA, three 240 kA, etc. The SLIM JIM has thermal sensors to eliminate the slow-burn condition, and has the capability to disconnect a failed suppression unit before overheating. They are available for either 120/240 single-phase or 120/208 three-phase circuits.

For More Information Circle No. 769

Aluminum Electrolytic Capacitors

Illinois Capacitor Inc., Chicago, IL, says that its SPH surface-mount aluminum electrolytic capacitors offer twice the life of standard types. Unlike other surface-mount electrolytics, the SPH is not a "can" in a box, according to the company. Its one-piece molded UL94V-O case saves space, allowing increased board density. Capacitance ranges from 0.47-150 µF at voltages from 4 WV to 50 WV DC. Operating temperature ranges from -55 °C to +105 °C, with a capacitance tolerance of ±20 percent at 20 °C (120 Hz). For automated assembly, the SPH is available on carrier tape and reel.

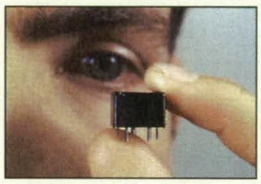
For More Information Circle No. 770



Complex Data Generator

The PI-2000 data generator from Pulse Instruments, Torrance, CA, has an almost infinite looping capability and can create digital data patterns at speeds and complexities that fulfill the most demanding requirements, according to the company. It provides clock rates up to 150 MHz, with both TTL and ECL capability. It has 32 kilobits per channel, and can be configured from 8 to 40 channels in 8-channel increments. Both RZ and NRZ modes of operation are provided. The PI-2000 includes a PC-compatible computer/controller with a 2.1-Gbyte hard drive for on-board pattern storage.

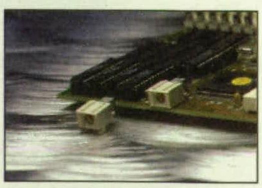
For More Information Circle No. 771



Ultraminiature Auto Relays

Aromat Corp., New Providence, NJ, introduces its NAiS brand CP Series automotive relays, rated with a nominal switching capacity of 20 A at 14 V DC (resistive). The company says that the relays combine a current-carrying capacity of 35 A at 80 °C for two minutes with a new low-profile space-saving design. The sealed-construction relays measure 14 mm long by 13 mm wide by 9.5 mm high. Ambient operating temperatures are -40 to 85 °C. The relays are designed to operate for a minimum of 10^7 mechanical operations at 120 cpm.

For More Information Circle No. 772



Modular PCB Power Connectors

The RN METPAK® 2 SPH two-piece power connector from Robinson Nugent Inc., New Albany, NY, is designed for PC board-to-board and board-to-backpanel high-power-distribution applications. The connectors, which handle 30 A, include a right-angle PCB-mounted receptacle that mates with a vertical mounted header. The company says the unit's high power-handling capacity and flexibility make it suitable for telecommunications, datacom, computer-server, and industrial-control applications.

For More Information Circle No. 773

Ball Grid Array Socket

Advanced Interconnections Corp., West Warwick, RI, calls its True BGA Socket a precision-engineered method for ball grid array socketing, emulation, repair/replacement, testing, and upgrade. Instead of soldering BGA devices directly to the PC board, Advanced's design allows the device to be dropped directly onto mating contacts, using a patent-pending pressure retention clamp that slides onto the BGA assembly. Available in a wide range of footprints and in tape and reel packaging for automated assembly, the socket has a coplanarity of less than the industry-standard 0.006 in.

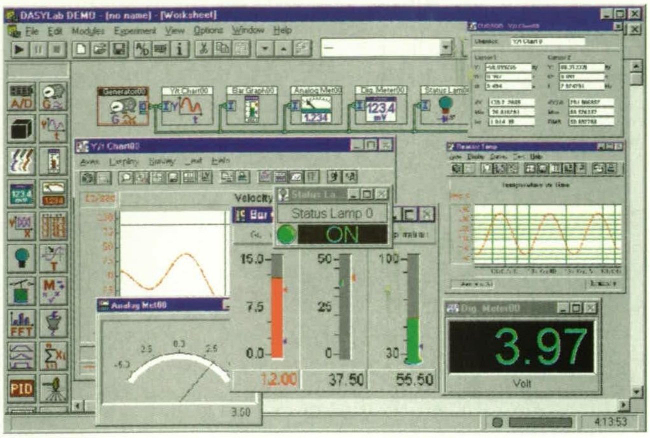
For More Information Circle No. 774

DC/DC Converter Modules

Astec America Inc., Carlsbad, CA, introduces the first models in what it calls the next generation of high-density DC-to-DC converter modules. The new 100-W single-output models have an input range of 36-75 V and no load/no capacitive limits. Available with outputs of 2.2, 3.3, 5, 12, or 24 V, the 48-V-input units are suitable for telecommunications and computer equipment as well as a variety of industrial applications. Astec says that the wide baseplate operating temperature range of -40 to 100 °C with no derating means that the modules can be used in the harshest environments.

For More Information Circle No. 775

Data Acquisition Software



DASYLab™ from IOtech is a Windows-based data acquisition application that provides effortless setup, acquisition, analysis, graphics, and control. DASYLab's no-programming, *connect-the-icons* environment eliminates the need for extensive training and programming time, providing flexible solutions in minutes, *not weeks*. Unlike other software that locks users into one brand of hardware, DASYLab supports data acquisition systems from a variety of suppliers, including IOtech's parallel-port, PC-Card, plug-in, and USB-based Daq products. DASYLab also supports IOtech's signal conditioning options for thermocouples, strain gages, accelerometers, and many other measurements. From $495.

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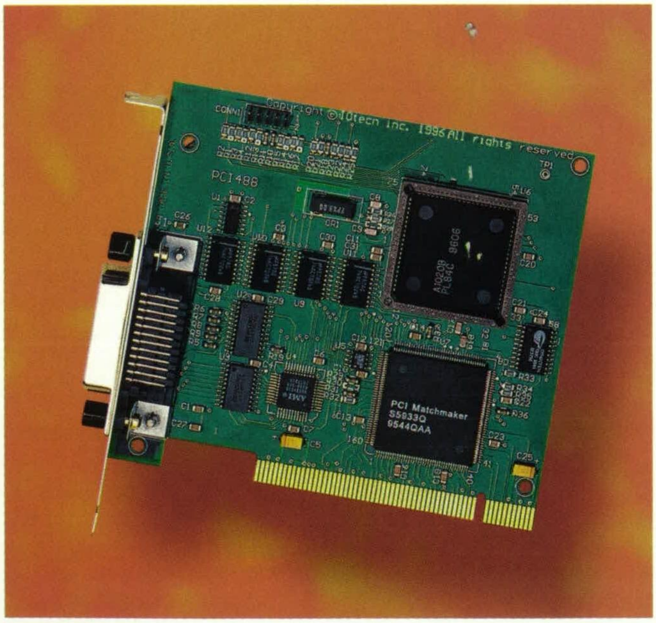
CIRCLE 402

PCI/IEEE 488 Interface



The Personal488/PCI™ interface from IOtech converts your PCI-bus PC into a high-performance IEEE 488.2-compliant controller capable of 1 Mbyte/s data transfer. In addition, it provides plug-and-play installation convenience, and 8 digital I/O lines. Software support includes Windows® 95 and Windows™ NT drivers for most programming languages, including Visual Basic®, C™, C++, Delphi, and LabVIEW®. IOtech's Personal488™ family also includes IEEE 488.2 interfaces for ISA and PC-Card buses. $495.

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CIRCLE 403

Portable Data Recorder

The ChartScan/1400™ paperless recorder from IOtech offers the familiar feel of a strip-chart recorder with the advanced features and ease-of-use of a PC-based data acquisition system. The recorder includes ChartView™ *Out-of-the-Box*™ software, which smoothly scrolls data over uniform grids that capture the look of chart paper. Expandable up to 128 isolated channels, the recorder offers a choice of four input connectors by way of plug-in scanning modules. Features include scan rates up to 147 channels/s, digital alarms, and more. Whether connected to a PC or used as a stand-alone instrument, ChartScan is an ideal solution for temperature and voltage applications. From $2690.

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CIRCLE 404

100-kHz Portable Data Logging

The new LogBook/300™ data acquisition system from IOtech provides high speed, low cost, and ease-of-use—*without requiring a PC at your test site*. The system features a 16-bit, 100-kHz A/D converter, and 16 single-ended or 8 differential analog inputs (expandable to 256). Ideal for a variety of portable and field applications, LogBook is smaller than a notebook PC and is AC and DC powerable. The system includes LogView™ *Out-of-the-Box*™ software, which permits sophisticated data logging, without programming. From $3495.

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CIRCLE 405

Special Coverage: Mechanical Technology

Passive Capture Joint With Three Degrees of Freedom

New joint allows quick connection between any two structural elements where rotation in all three axes is desired.

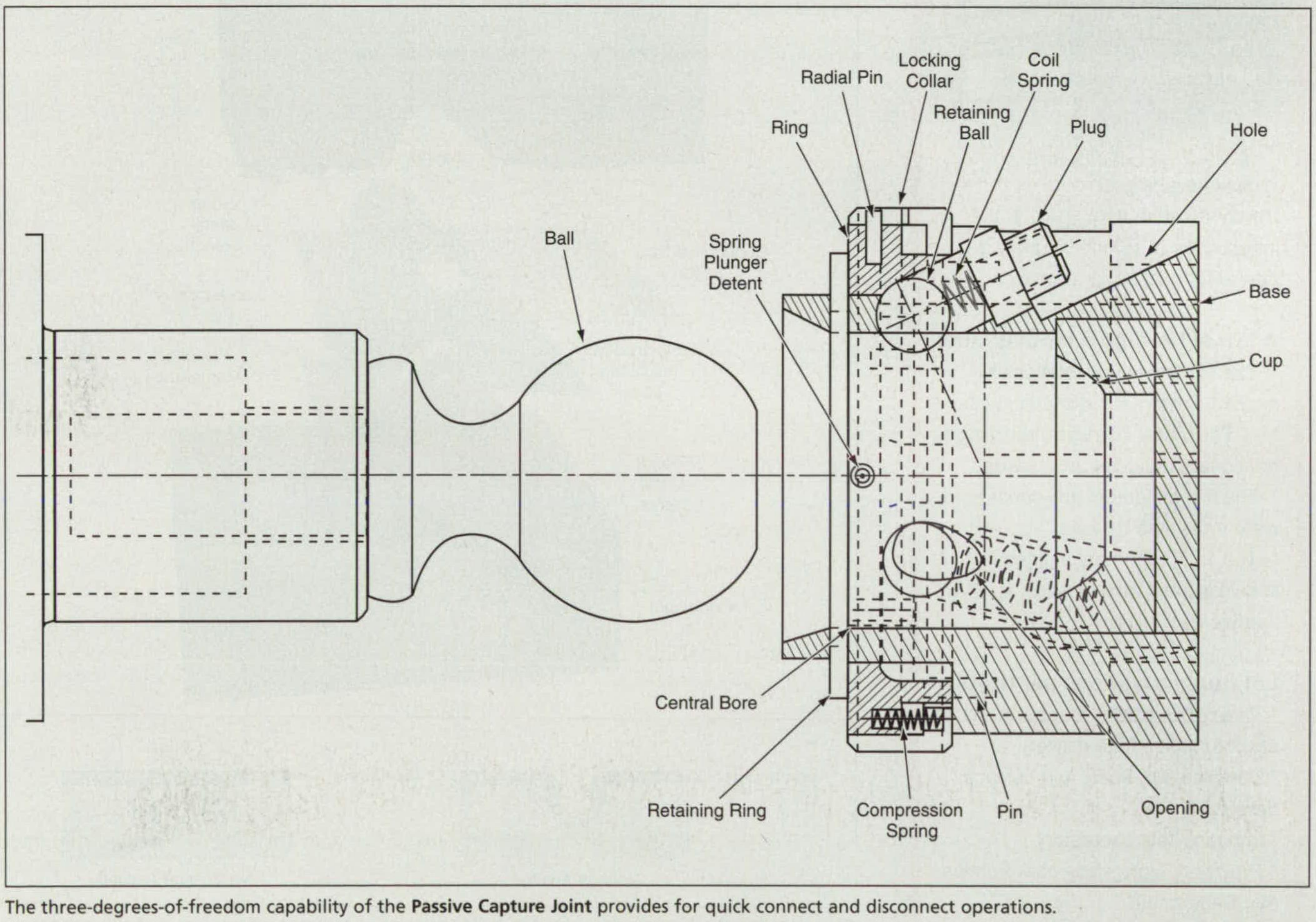
Marshall Space Flight Center, Alabama

A new joint, proposed for use on an attachable debris shield for the International Space Station Service Module, has potential for commercial use in situations where hardware must be assembled and disassembled on a regular basis. This joint can be useful in a variety of applications, including replacing the joints commonly used on trailer-hitch tongues and temporary structures, such as crane booms and rigging. Other uses for this joint include assembly of structures where simple rapid deployment is essential, such as in space, undersea, and in military structures.

This new joint allows for quick connection between any two structural elements where it is desirable to have rotation in all three axes. The joint can be fastened by moving the two halves into position. The joint is then connected by inserting the ball into the bore of the base. When the joint ball is fully inserted, the joint will lock with full strength. Release of this joint involves only a simple movement and rotation of one part. The joint can then be easily separated.

Most passive capture devices allow only axial rotation when fastened — if any movement is allowed at all. Manually- or power-actuated active joints require an additional action, or power and control signal, as well as a more complex mechanism.

The design for this new joint is relatively simple. It consists of two halves, a ball mounted on a stem (such as those used on a common trailer-hitch ball) and a socket. The socket contains all the moving parts and is the important part of this invention. The socket also has a base, which contains a large central cylindrical bore ending in a spherical cup.



The three-degrees-of-freedom capability of the **Passive Capture Joint** provides for quick connect and disconnect operations.

This work was done by Bruce Weddendorf and Richard A. Cloyd of the **Marshall Space Flight Center**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Mechanics category.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Marshall Space Flight Center; (205) 544-0021. Refer to MFS-31146.

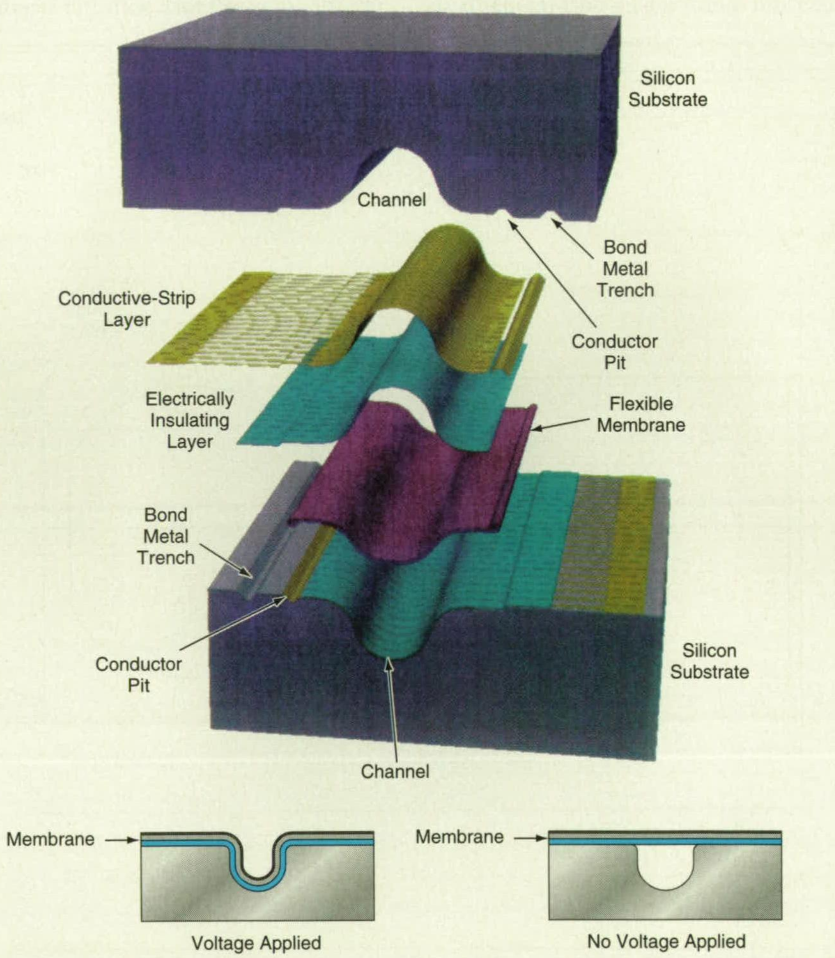
Microscopic Heat Exchangers, Valves, Pumps, and Flowmeters

Forced-flow heat-transfer systems would be made by micromachining.

NASA's Jet Propulsion Laboratory, Pasadena, California

Microscopic forced-flow heat-transfer systems containing heat exchangers, flow channels, electrostatically driven peristaltic pumps, and related components have been proposed. These systems would be made largely of silicon, by use of micromachining processes similar or identical to those used to make integrated circuits. These microscopic heat-transfer systems could thus be made as integral parts of integrated circuits: For example, charge-coupled-device (CCD) imaging circuits in infrared cameras could be cooled very effectively by incorporating such systems to circulate cryogenic fluids within the CCD substrates.

The figure illustrates a dual-cavity push-pull embodiment of an electrostatically driven peristaltic pump. The pump channels would be etched into silicon substrates, which are bonded together with an electrically conductive flexible membrane sandwiched between them. The channels would be lined with electrically conductive strips covered with electrically insulating material and separated from each other by electrically insulating barriers. By applying a suitable voltage between the membrane and the conductive strips of each channel in succession, one would cause the membrane to be electrostatically pulled into the channel at successive positions along the channel. Dual interlaced and interlocked shift registers enable alternate inversions of bit-stream sequences and multiple membrane "bubbles" that move down the channel, pushing entrapped fluid in front of each membrane "wall" and pulling the fluid



Electrostatic Attraction would be used to pull the flexible membrane into, across, and along the channels: this would generate peristaltic waves in the membrane to pump a fluid along the channel.

behind each membrane "wall." This pump architecture represents a true two-dimensional analog of a peristaltic mechanism that is valveless, impervious to gas-bubble entrapment, does not require priming, and is self purging. The device is a digital pump that may be single-stepped to function as a valve or, by counting the number of clocked bits, is a precision flowmeter.

A heat exchanger consisting of micromachined channels in a thermally conductive material would be designed to maximize heat-transfer surface area and to provide effective convective coupling of heat between the pumped fluid and the channel surfaces at the expected flow speeds. The use of microscopic channels would make it possible to achieve low conduction and convection losses, with consequent high thermal coupling and short characteristic times for decay of thermal transients.

This work was done by Frank T. Hartley of Caltech for **NASA's Jet Propulsion Laboratory.** *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Machinery/Automation category.*

This is the invention of a Caltech/JPL employee, and a patent application has been filed. Inquiries concerning license for its commercial development may be addressed to the inventor:

Frank Hartley
JPL
MS 125-177
4800 Oak Grove Drive
Pasadena, CA 91109
(818) 354-3139

Refer to NPO-19093, volume and number of this NASA Tech Briefs *issue, and the page number.*

Miniature Side-Bore Sample-Acquisition Mechanism

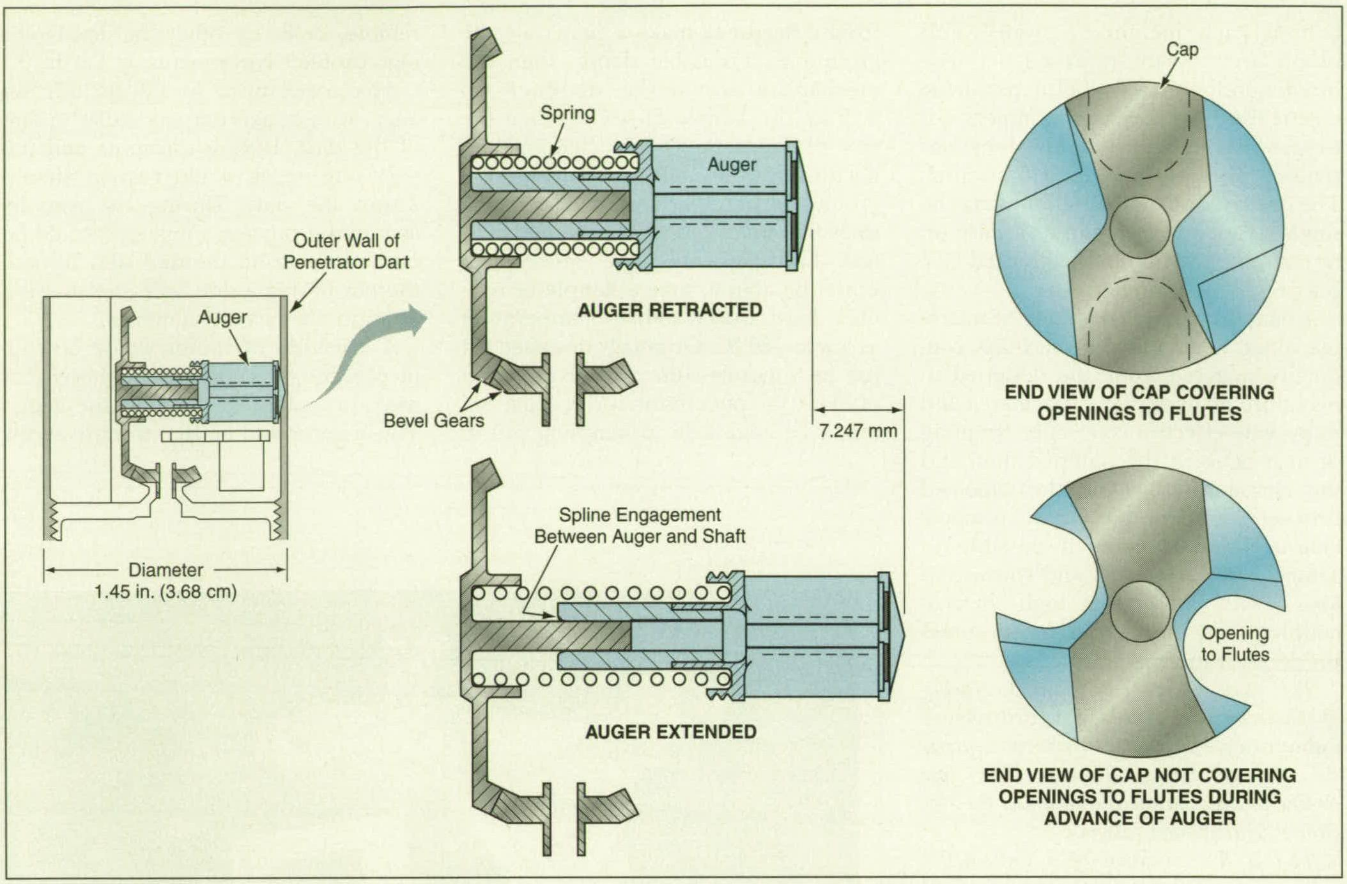
This mechanism could withstand large deceleration and would function in extreme cold.

NASA's Jet Propulsion Laboratory, Pasadena, California

The figure illustrates various aspects of a proposed mechanism that would be mounted in an instrumented penetrator dart for use in acquiring a sample of soil. In operation, the dart would be dropped from a height to make it penetrate the ground to a suitable depth, then the mechanism would be activated to acquire the sample of soil through the side of the dart. The mechanism and dart would be built to withstand a ground-impact deceleration of as much as 30,000 times the acceleration of normal Earth gravity. The mechanism would be able to take a sample of relatively hard, frozen soil at a temperature as low as –80 °C. Originally designed for use in remotely controlled exploration of Mars, the penetrator and mechanism might be adaptable to sampling soil in remote, cold, or otherwise hostile or inaccessible environments on Earth.

The mechanism would include an auger with its axis perpendicular to that of the dart. During transport and impact, the auger would remain stowed within the dart. During the sample-acquisition process, the auger would be pushed out from the dart and turned, thereby boring a side hole and drawing soil into the dart for sampling.

A brushless dc motor would be coupled through a right-angle bevel-gear drive to a shaft for turning the auger. The auger would be free to slide axially



The **Entire Mechanism Would Fit** within the penetrator dart.

along the shaft, but a square spline would constrain the auger to rotate with the shaft. The auger would be spring-loaded toward extension, but prior to use, it would be restrained against extension by engagement between mating threads on the auger and an interior structural component of the dart.

To prevent the flutes of the auger from ingesting soil before reaching the desired depth, the openings to the flutes would be covered by a drill cap during transport and impact. During the first 70° of rotation of the auger, the drill cap would not rotate; thus, the auger would rotate relative to the cap, bringing the openings to the flutes out from under the cap. Upon reaching 70°, the auger would engage the cap; thereafter the auger and cap would rotate together, so that the openings to the flutes would remain exposed.

This work was done by Tommaso P. Rivellini and Christopher J. Voorhees of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Machinery/Automation category.*
NPO-20163

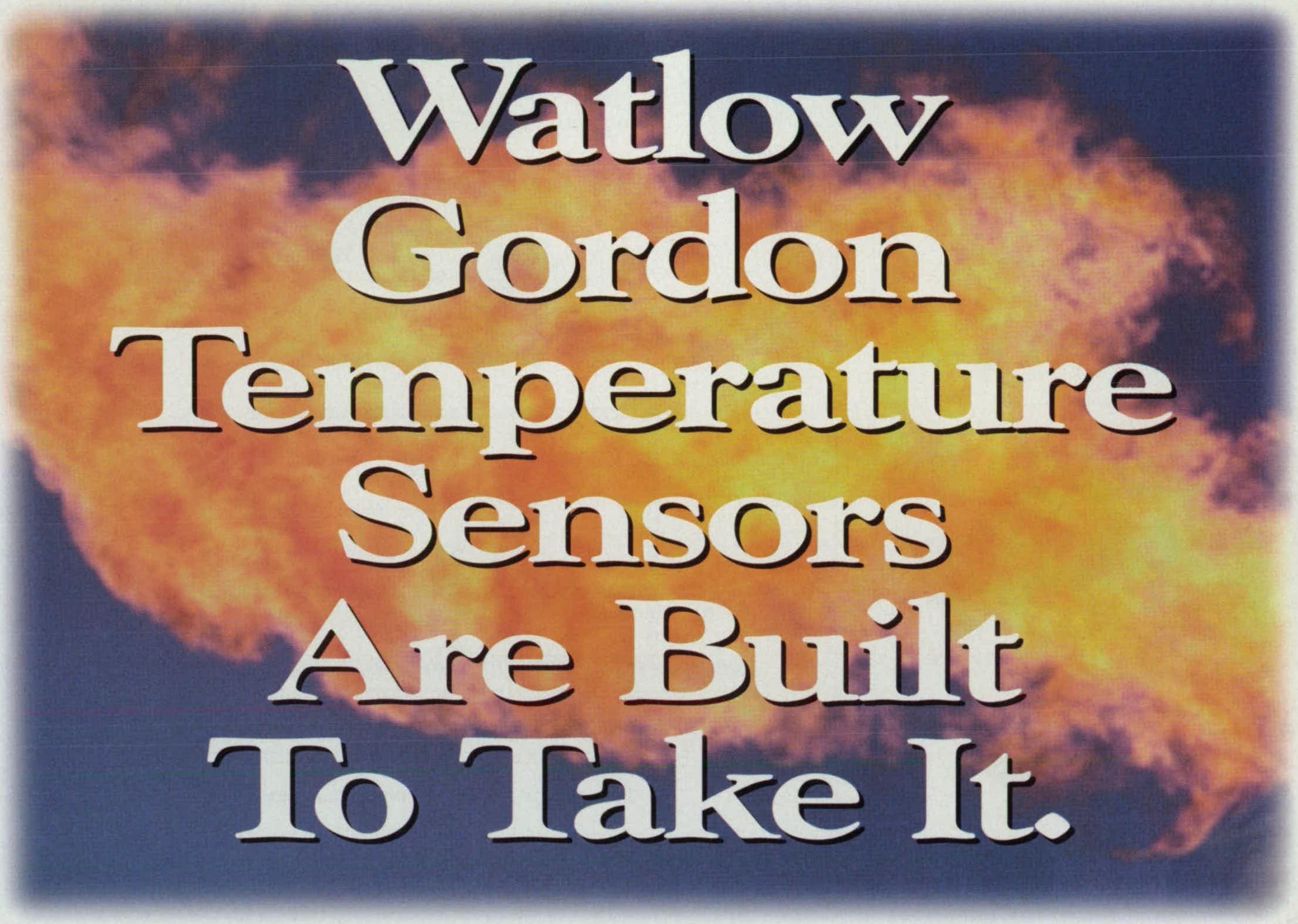
Emergency-Shutoff Valves Would Be Triggered by Acceleratons

These valves could stop flows of liquids in earthquakes, explosions, and vehicular impacts.

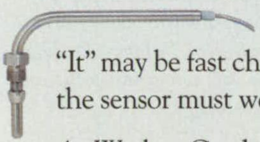
NASA's Jet Propulsion Laboratory, Pasadena, California

Automatic valves have been proposed for shutting off flows of liquids when abnormally large accelerations occur. These valves could be used, for example, to prevent outflows of flammable, valuable, or toxic liquids from pipelines that have been struck by vehicles or that have become involved in earthquakes or explosions. Actuation of the proposed valves would not depend on sources of electrical or fluid power, which would likely be unavailable during the emergencies in which the valves would be needed. Actuation would not even depend on pressurization of the liquids to be contained. Instead, the valves would operate similarly to spring-actuated rat traps, and like such traps, the valves could also be opened or closed manually.

The shaft for opening and closing a typical proposed valve would be connected to a lever, which would be spring-loaded toward the closed position. The lever would be turned against the spring load to open the valve (see figure). At the fully open position, an approximately hemispherical tip on the lever would face a similar tip on a stationary cocking stop. An inertial triggering object (in a ball in the case illustrated) would be placed between the tips to keep the valve open. The ball would be held in place by



(Whatever "It" May Be.)



"It" may be fast changes in pressure. Vibration. Or extreme temperature ranges. Whatever "it" may be, the sensor must work.

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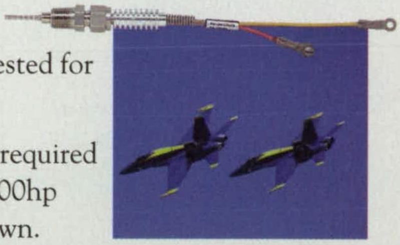

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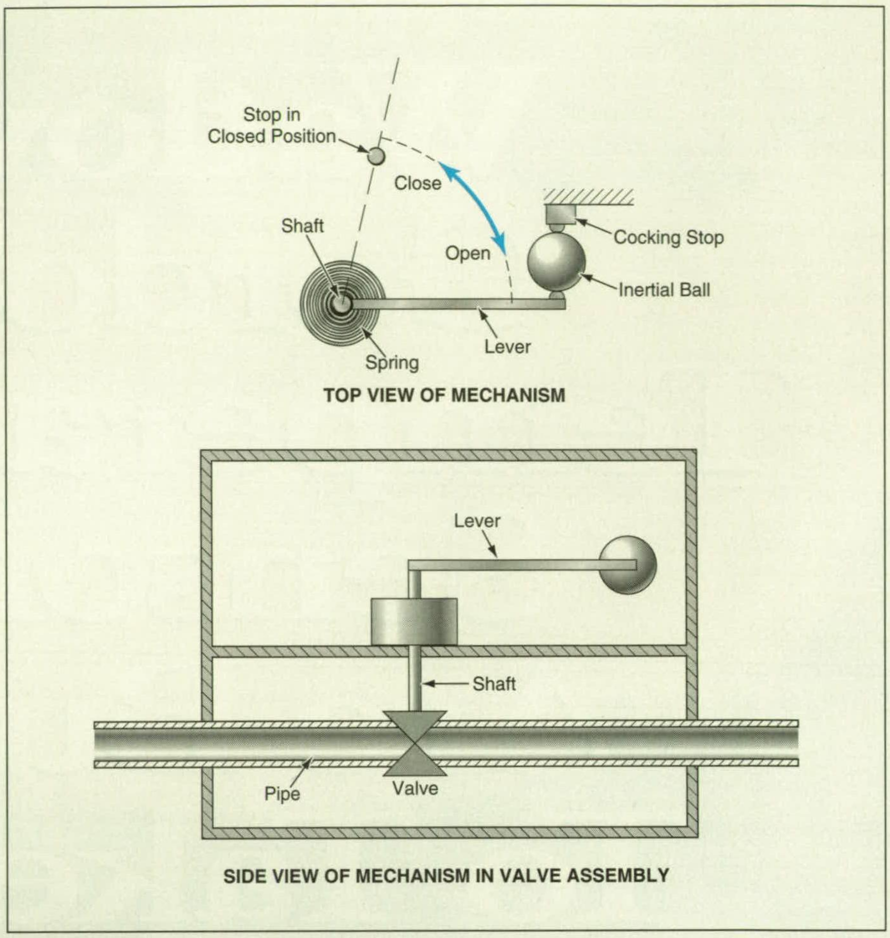


Acceleration Would Trigger the mechanism by dislodging the ball from between the tips on the lever and the cocking stop. The spring would then act on the lever, turning the shaft to close the valve.

spring force and associated friction. A sufficiently large acceleration would dislodge the ball, allowing the spring to turn the lever and shaft to the closed position. The triggering sensitivity would vary inversely with the inertial force needed to overcome friction to slide the ball out from between the tips; this force would depend on the choice of the materials, sizes, shapes, and surface finishes of the ball and tips.

This work was done by Andrew D. Morrison of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Mechanics category.*

NPO-20114

Procedure for Designing Safe Robots

Engineering compromises between performance and safety can be made systematically.

John F. Kennedy Space Center, Florida

A methodology for designing robots provides for satisfying both safety and performance requirements. Heretofore, most robot-design efforts have been focussed on maximizing performance, with only incidental regard for safety, under the assumption that humans and delicate equipment would be excluded from robot workspaces during robotic operations. The present methodology was developed out of recognition of the need to ensure safety for humans while realizing the potential ability of robots and humans working together to perform a broader spectrum of tasks than either can perform alone.

The methodology is implemented by a formal design procedure in which quantitative evaluations are performed to effect compromises between the inevitably competing demands of performance and safety. The procedure comprises five main steps and a number of sub-steps (see Figure 1).

The first two steps, which can be simultaneous, are the determination of task requirements and the determination of safety requirements. "Task requirements" as used here denotes such quantitative performance specifications as robot-tip velocities, robot payloads, robot position and force accuracies, and measures of robot dexterity. For a given application and task, minimum acceptable values can be assigned to these specifications to quantify minimum acceptable performance.

"Safety requirements" as used here denotes the set of all robot-performance measures that are related to safety in that they indicate degrees to which robots can harm humans. Such measures include robot static and impact contact force, robot static and impact vise or pinch forces, robot static and impact contact forces, and crushing forces from robot weights. For a given application and task, maximum allowable values can be assigned to these measures to specify safety limits.

The next step is the selection of the top-level robot design. More specifically, this means the selection of the kinematics, range of motion, and geometry of a robot to accomplish the task as specified in the first step.

In the following step, one determines measures of the speed and strength of the robot on the basis of the top-level robot design and the safety requirements. This step is divided into the following four substeps:

1. Develop mathematical models of robot forces, velocities, and energies to relate design parameters to safety and performance variables.
2. Using the models developed in substep 1, make a safety diagram, which is a plot showing the boundary (denoted the "safety envelope") between safe and unsafe values of two or more safety-related performance measures. Also plot the boundary (denoted the "task envelope") of the task requirements for these performance measures on the safety diagram (see Figure 2).
3. Select target performance specifications (e.g., a value of tip velocity and a value of payload weight) that lie within the intersection of the safety and task envelopes.
4. Select the joint torques and velocities needed to achieve the target performance specifications and design the robot joints and actuators accordingly.

The last step is the application of guidelines for safe design. Six guidelines have been formulated through analysis of those safety and task specifications that are mutually independent (or at least nearly so). Each guideline represents a strategy for independently optimizing some aspect of either safety or performance.

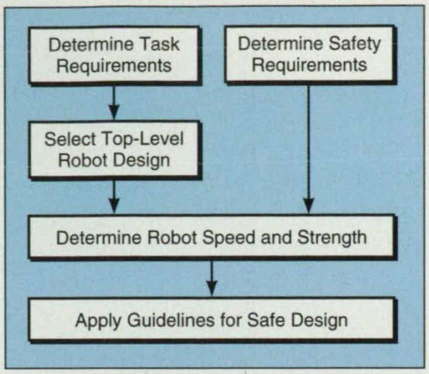


Figure 1. This **Five-Step Procedure** implements the methodology for designing safe robots.

The guidelines are the following:

1. Maximize robot accuracy,
2. Maximize robot dexterity.
3. Minimize robot weight.
4. Eliminate pinch points and maximize potential vise radii.
5. Maximize robot contact area.
6. Maximize robot padding thickness.

These guidelines, if followed during the design process, can help ensure a high-performance, safe robot design.

(Continued on next page)

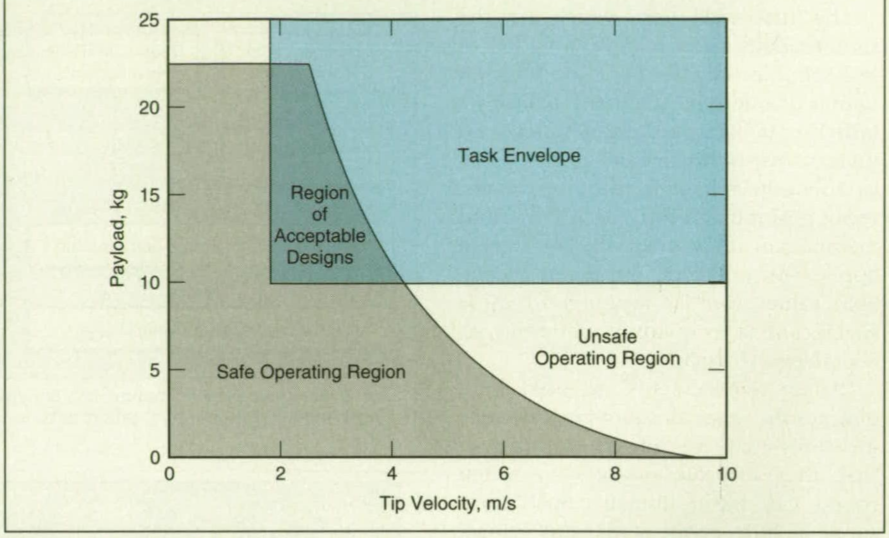


Figure 2. This **Safety Diagram** with superimposed task envelope for a typical robot illustrates the margin available for designing to satisfy both safety and performance requirements. The intersection of the design and safety envelopes represents the ranges of tip-velocity and payload values of acceptable designs.

This work was done by Karl T. Ulrich, Timothy D. Tuttle, Joseph P. Donoghue, and William T. Townsend of Barrett Technology, Inc., for **Kennedy Space Center**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Machinery/Automation category.*

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to

William T. Townsend
Barrett Technology, Inc.
139 Main Street
Kendall Square
Cambridge, MA 02142
(617) 252-9000

Refer to KSC-11849, volume and number of this NASA Tech Briefs *issue, and the page number.*

Automatic Thermal Switches With No Moving Parts

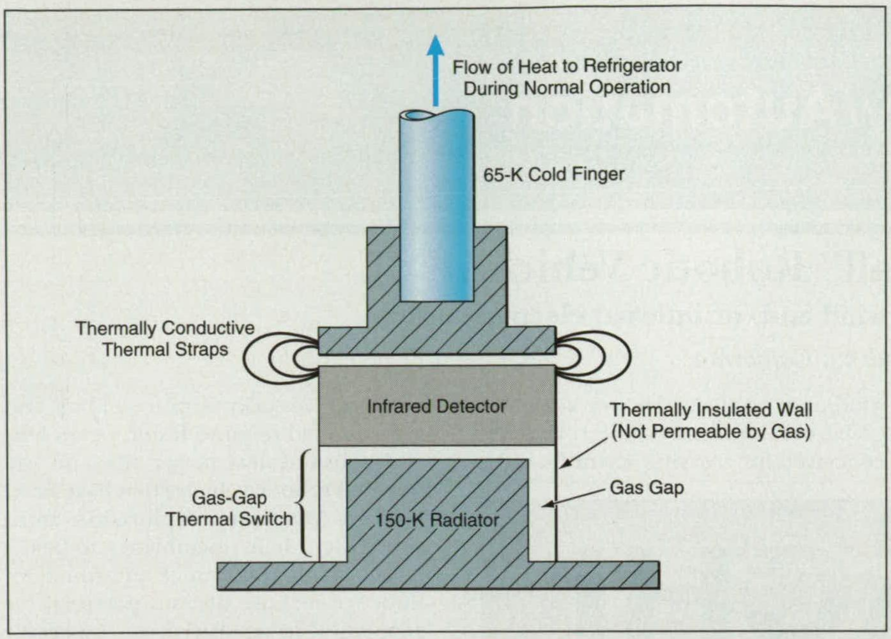
The conductances of novel gas-gap thermal switches would increase with temperature.

NASA's Jet Propulsion Laboratory, Pasadena, California

Quasi-thermostatic gas-gap thermal switches have been proposed. These switches would operate automatically, would contain no moving parts, would not require power supplies or controls, would not consume any materials, and would not create vibrations. The operation of a switch of this type would be based on the increase, with temperature, in the vapor pressure of a condensible fluid in a gap; the effective thermal conductance across the gap would increase with vapor pressure and thus with temperature. The design of the gap and the fluid would be chosen so that the thermal conductance across the gap would increase sharply with temperature in the desired switching temperature range.

In the original intended application, a thermal switch of this type would provide a thermal connection for backup radiative cooling of an infrared detector to a temperature of about 150 K in the event of failure of a refrigerator that would ordinarily provide cooling to 65 K (see figure). The fluid chosen for this application is carbon dioxide, which would condense in solid form on the infrared-detector side of the gap during normal operation at 65 K. Because the vapor pressure of carbon dioxide is only 10^{-14} torr ($\approx 10^{-12}$ Pa) at 65 K, the effective thermal conductance across the gap during normal operation would be negligible; that is, the radiator could be regarded as thermally disconnected from the infrared detector.

In the event of failure of the refrigerator, the temperature of the infrared detector would rise toward 150 K, causing some of the carbon dioxide to



The Gap Would Be Effectively Empty and thus heat would not be conducted across the gap at an intended normal operating temperature of 65 K. At a higher temperature (150 K), the gap would be filled with carbon dioxide, rendering the gap thermally conductive, so that the infrared detector would be cooled by the radiator.

vaporize and fill the gap. At 150 K, the vapor pressure of carbon dioxide is 2.4 torr (320 Pa), and the effective thermal conductance across the gap would be about the same as though the carbon dioxide were at full atmospheric pressure and temperature. This level of thermal conductance would provide an effective thermal connection between the infrared detector and the radiator.

Upon resumption of normal operation, the vapor pressure of the carbon dioxide would decrease along with the temperature. At an intermediate temperature of 125 K, the vapor pressure of carbon dioxide is 1.5×10^{-2} torr (about 2 Pa), and the resulting effective thermal conductance across the gap would be of the order of 10^{-2} times that at 150 K; thus, the infrared detector would be effectively thermally disconnected from the radiator and could therefore be cooled more effectively by the refrigerator to the desired operating temperature of 65 K.

Gas-gap thermal switches based on the same principle could be designed for other temperature ranges, using other fluids. For example, water vapor could be used as the gap fluid for switching between active and passive means for cooling habitable spaces. For another example, mercury could be used as the gap fluid for switching at a temperature of about 450 K.

This work was done by Jack Jones and Dean Johnson of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Physical Sciences category.*
NPO-19545

Lightweight "Beach-Ball" Robotic Vehicles

These rovers could be driven by wind and/or internal electric power.

NASA's Jet Propulsion Laboratory, Pasadena, California

Lightweight, inflatable robotic vehicles (rovers) that superficially resemble beach balls and that could be driven by wind and/or electric power are undergoing development. These rovers were conceived for carrying scientific instruments across rocky terrain on Mars, and are intended to move faster, weigh less, and consume less power than do the wheeled robotic vehicles that have been used in planetary exploration until now. Given their resemblance to beach balls in both appearance and function, these rovers have obvious potential for adaptation to terrestrial use, especially as toys.

One previous "beach-ball" rover concept was that of an uncontrolled rover little different from an ordinary beach ball. Another previous concept was that of a spherical balloonlike shell, within which motor-driven weights would be moved along internal diametral tethers to shift the center of gravity to make the shell roll [this concept was described in "'Beach-Ball' Robotic Rovers" (NPO-19272), *NASA Tech Briefs*, Vol. 19, No. 11, (November 1995), page 83.]

The present concept differs from both previous concepts, though it incorporates some elements of both. The present concept encompasses both single- and double-ball rovers (see Figure 1). A single-ball rover would contain a diametral rod that would serve as an axle. A payload-and-motor-drive assembly could move itself along or across the axle. To enable the ball to roll freely in the wind, the payload mass would be centered in the ball. To stop or prevent rolling, the payload mass would be shifted away from the center, either along or across the axle. With the payload mass hanging down from the axle, another motor drive at one end of the axle could exert torque on the ball to make the ball roll in the absence of wind. Steering could be effected by moving the payload left or right along the axle during rolling or driving.

In a double-ball rover, the balls would be connected by an external axle collinear with their internal axles. The payload-and-motor-drive assembly would be mounted on the external axle. Both balls would be equipped with independent end-of-axle motor drives similar to those of a single-ball rover, for driving or steering. The double-ball

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TECHNO 2100: VentureStar™: Launch to the Future is produced by the multi-award winning Information Television Network, and is underwritten by the X-33 Team: Lockheed Martin, Boeing Rocketdyne Division, AlliedSignal Aerospace, Sverdrup and BF Goodrich Aerospace.

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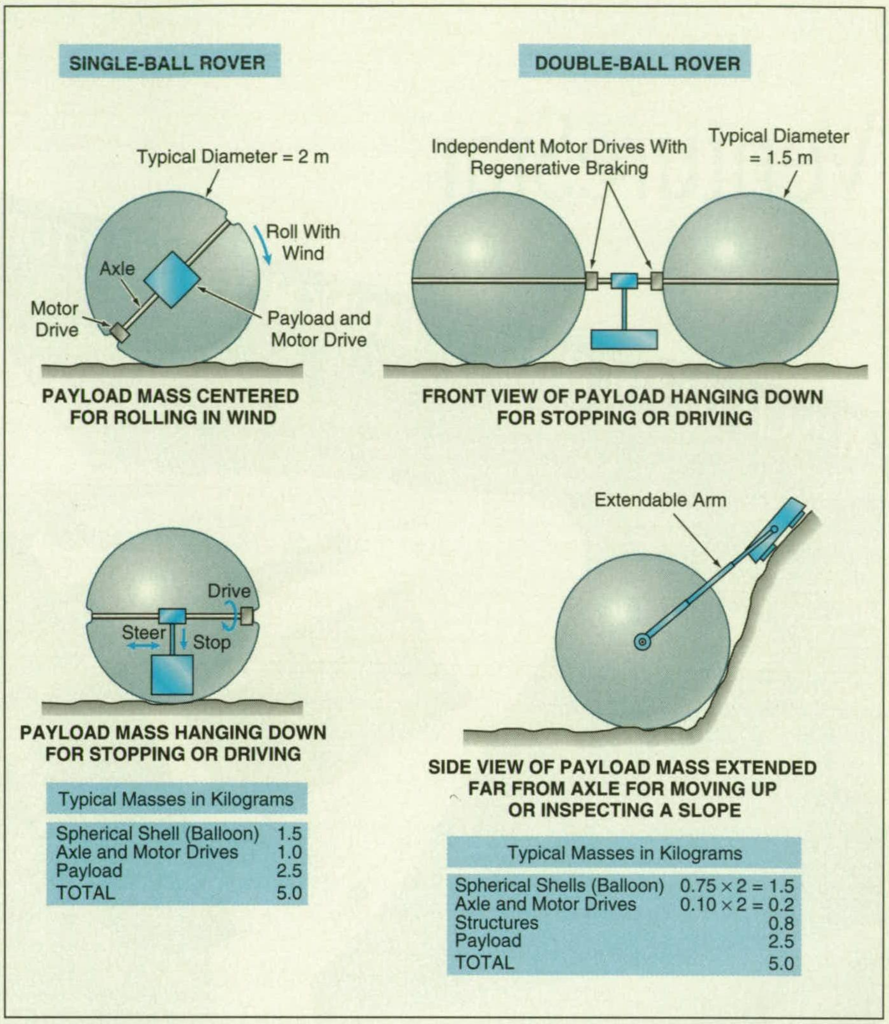

Figure 1. These **"Beach-Ball" Rovers** would weigh less, travel faster, and consume less power than do older wheeled robotic exploratory vehicles.

rover could roll with the wind or move under its own power, similarly to a single-ball rover. In addition, the external payload mass could be extended far from the external axle to obtain additional torque to climb a rock or a steep slope. A variation of this design has been fabricated and tested with the extendable arm connected to a "slave" wheel that is pulled behind the two drive wheels (see Figure 2).

This work was done by Jack Jones and Andre Yavrouian of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Machinery/Automation category. NPO-20283*

Figure 2. A **Working Three-Wheeled Inflatable Rover** with an upper simulated photovoltaics sphere has been enlarged fourfold to show anticipated size for a lightweight Mars rover.

Laser Anemometer Measures Flow in a Centrifugal Compressor

High-resolution data are representative of flows in practical centrifugal compressors.

Lewis Research Center, Cleveland, Ohio

Detailed measurements of complex flow fields within the NASA Low Speed Centrifugal Compressor (LSCC) have been acquired. The measurement data provide insight into the fundamental physics of flow in centrifugal compressors, and can be used to assess computational fluid dynamics codes and to develop flow-physics models. The resultant benefit is better predictive computational tools and shorter design cycle times.

Centrifugal compressors are widely used in auxiliary power-unit turbochargers, small gas turbine engines, gas-processing plants, and other applications. However, in comparison with their axial-flow counterparts, centrifugal compressors have generally been investigated in less detail.

The LSCC was designed to be representative of conventional high-speed subsonic compressors typically employed in small gas turbine engines. However, the measurements were acquired in the LSCC at low subsonic speeds, where the flowing air behaves as though it were essentially incompressible. As such, the measurements are reasonably representative of what would be found in many centrifugal pumps. The measurement data can therefore be used to validate any aerodynamical computer code that is applicable to centrifugal pumps.

The large size and low speed of the LSCC enable the detailed measurement, by use of a laser anemometer, of all three components of velocity within passages between rotor blades, with a spatial resolution unparalleled in investigations of high-speed compressors. For example, three-dimensional viscous flows that occur very near the surfaces of blades were measured in detail. Complementary measurements of static pressures on blade and shroud surfaces, pressure measurements by pneumatic probes at various positions across inlet and exit surfaces were acquired, and flow-visualization tracings were also acquired. Collectively, the results of the experiments in the LSCC constitute a benchmark set of high-quality data for assessing the predictive capabilities of state-of-the-art three-dimensional viscous-flow computer codes.

Figure 1 illustrates the LSCC impeller and the locations of laser-anemometer measurements. The upper part of Figure 2 shows results of velocity measurements taken at the 64-percent meridional chord position, indicating the extent of the through-flow-velocity deficit characteristic of centrifugal-compressor flow fields. The lower part of Figure 2 illustrates the nature of secondary flow measurements at the same location, along with some details that demonstrate the resolution of measurements acquired in viscous-flow regions near blade surfaces.

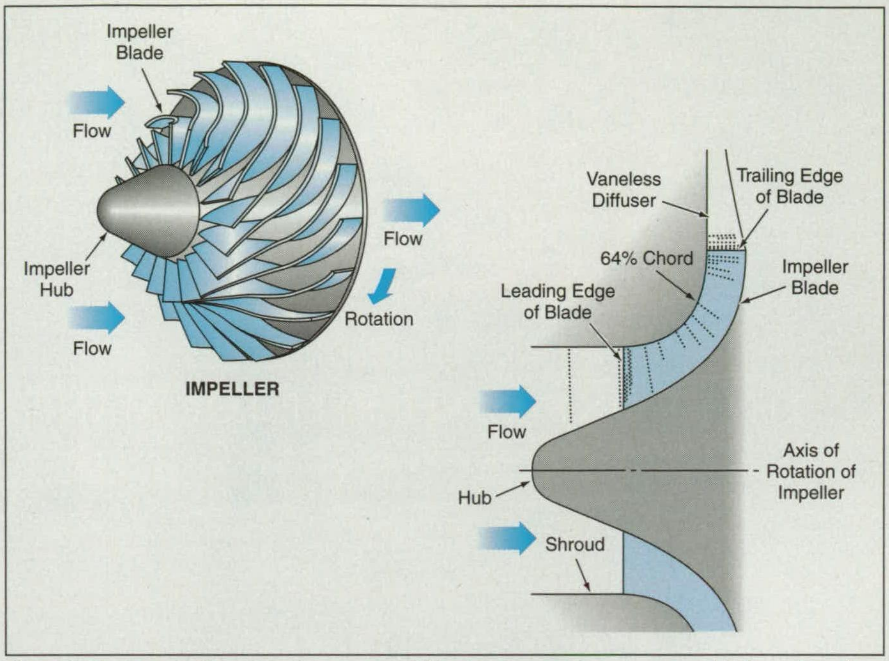

Figure 1. The **Dots Indicate Locations**, most within the passages between rotor blades, where flow velocities were measured by a laser anemometer.

This work was done by Randall M. Chriss, Anthony J. Strazisar, and Jerry R. Wood of **Lewis Research Center** *and Michael D. Hathaway of the U. S. Army Research Laboratory. For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Machinery/Automation category.*

Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Lewis Research Center, Commercial Technology Office, Attn: Tech Brief Patent Status, Mail Stop 7–3, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-16417.

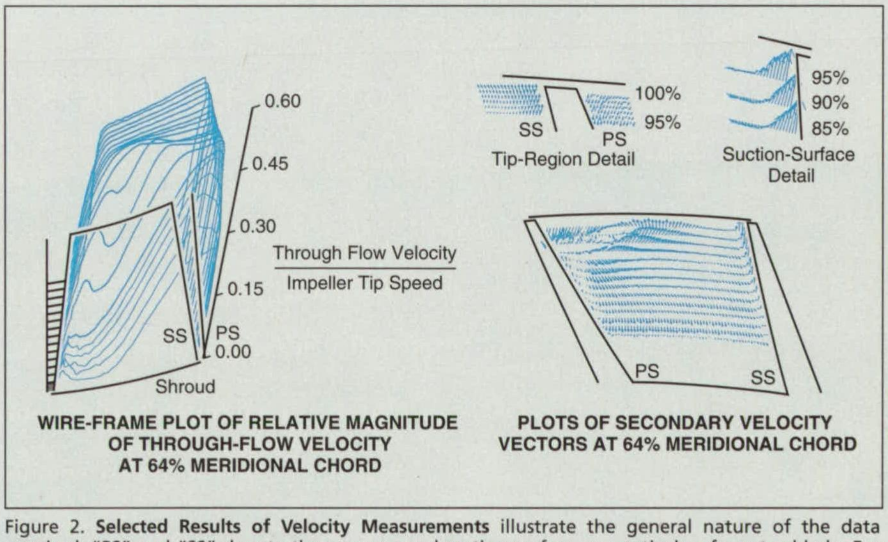

Figure 2. **Selected Results of Velocity Measurements** illustrate the general nature of the data acquired. "PS" and "SS" denote the pressure and suction surface, respectively, of a rotor blade. For clarity, different vector scales are used in the main and detail plots of velocity vectors, and the pitch-wise spatial resolution of the main plot is 1/3 that of the detail plots.


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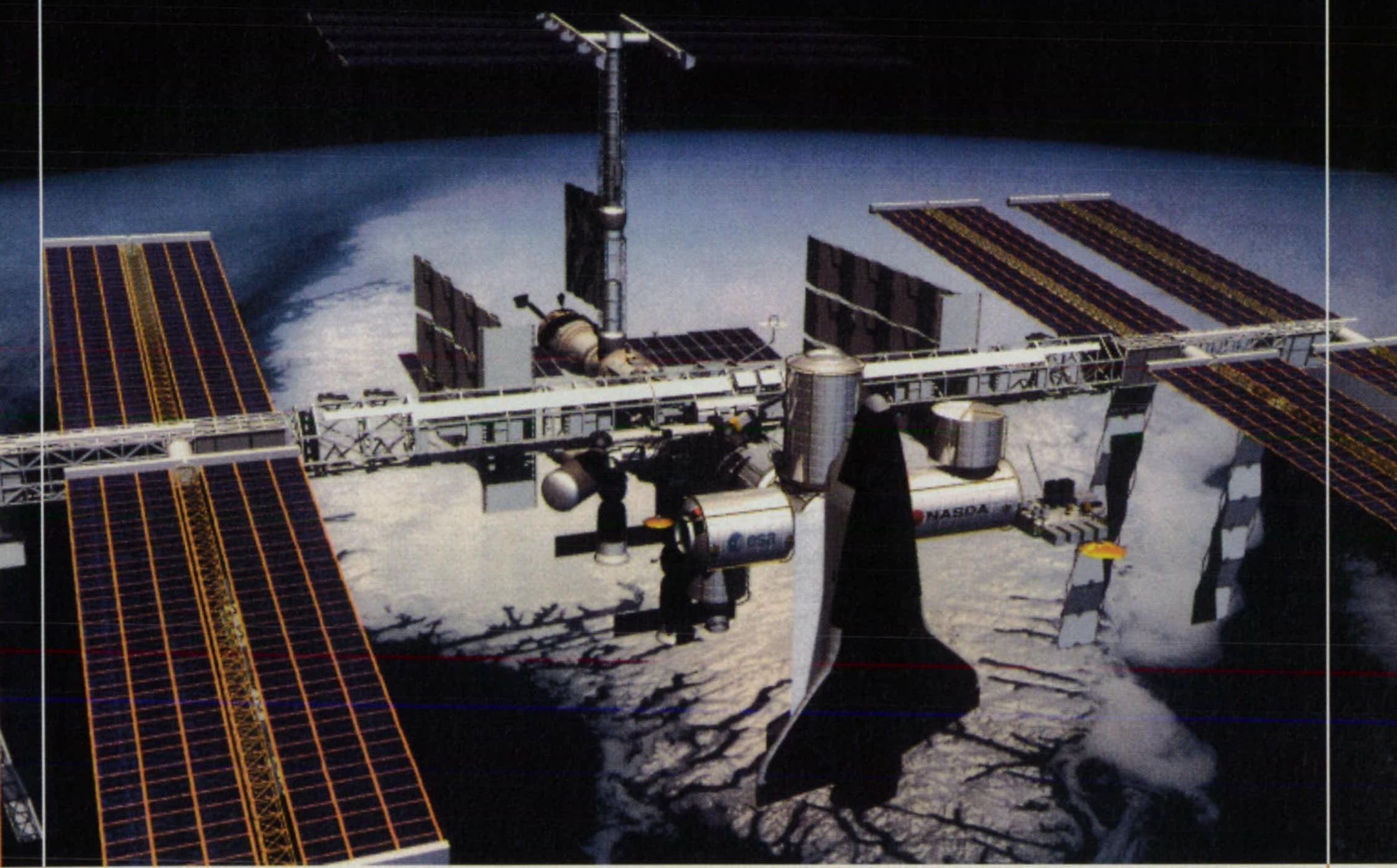
The Technology of Space Station

NASA has had its sights set on an International Space Station for more than 30 years. Now, with 16 partner nations and hundreds of contractors and suppliers from around the world, the station is becoming a reality. With the first component scheduled for launch this year, NASA Tech Briefs looks at the technology behind the International Space Station, including commercial products used in its development and deployment, the pioneering technologies that will be tested on-board, and the expected technological breakthroughs in areas such as electronics, medicine, and communications.



ISS: Challenges & Opportunities

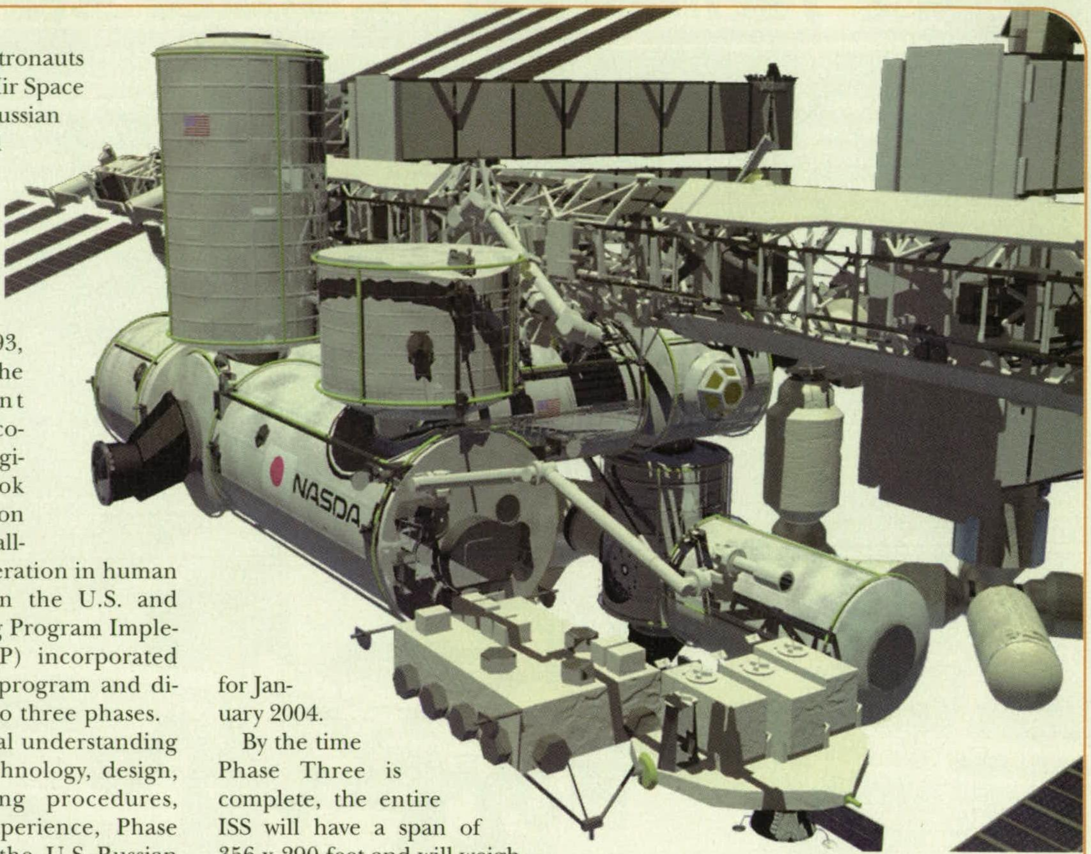
The International Space Station (ISS) is the largest cooperative scientific project in history, combining resources and technological input from 16 nations — the United States, Canada, Japan, Russia, Italy, Denmark, Norway, Belgium, the Netherlands, France, Spain, Germany, Sweden, Switzerland, the UK, and Brazil. ISS was conceived by NASA almost 30 years ago as "the next logical step" to follow the Apollo program. The station became a formal NASA project in 1984, when President Reagan officially established the goal of developing a permanently inhabited outpost in space. Canada, Europe, and Japan accepted invitations to join the U.S. in what was initially called "Space Station Freedom."

By 1993, budget constraints and concern about whether the program could meet key deadlines prompted the Clinton Administration and NASA Administrator Daniel S. Goldin to call for a redesign of the space station. The "Crystal City" redesign project developed three options for a space-station program. The first — or "Alpha" — option was chosen, and remains the basis for the project now officially known as "International Space Station Alpha."

The Alpha option required using as much of the original "Freedom" hardware and systems as possible, and about 75 percent of these designs will be incorporated into the ISS. The plan also called for the continued involvement of all international partners and for designs to be implemented within strict budget constraints. During the Crystal City redesign, the developing relationship between the U.S. and the newly formed Russian Republic had a major impact on the ISS.

Beyond Mir

A major goal of the Administration was to involve Russian scientists and engineers in constructive activities, to help curb further transfer of missile and nuclear technology. The scope of the 1992 Human Space Flight agreement was expanded to include long-



term flight of U.S. astronauts aboard the Russian Mir Space Station, flight of Russian cosmonauts aboard NASA's Space Shuttle, Shuttle/Mir docking missions, and a joint science program.

In September 1993, the first meeting of the U.S.-Russian Joint Commission on Economic and Technological Cooperation took place. The Commission issued a statement calling for further cooperation in human space flight between the U.S. and Russia. The resulting Program Implementation Plan (PIP) incorporated Russia into the ISS program and divided the project into three phases.

To promote mutual understanding of each nation's technology, design, development, testing procedures, and operational experience, Phase One expanded on the U.S.-Russian activities named in the 1992 agreement. Terms included building a cadre of astronauts and support staff trained in long-term space flight and the demonstration and testing of ISS technology. Phases Two and Three culminate in the assembly and deployment of the ISS, involving the U.S., current international partners, and Russia.

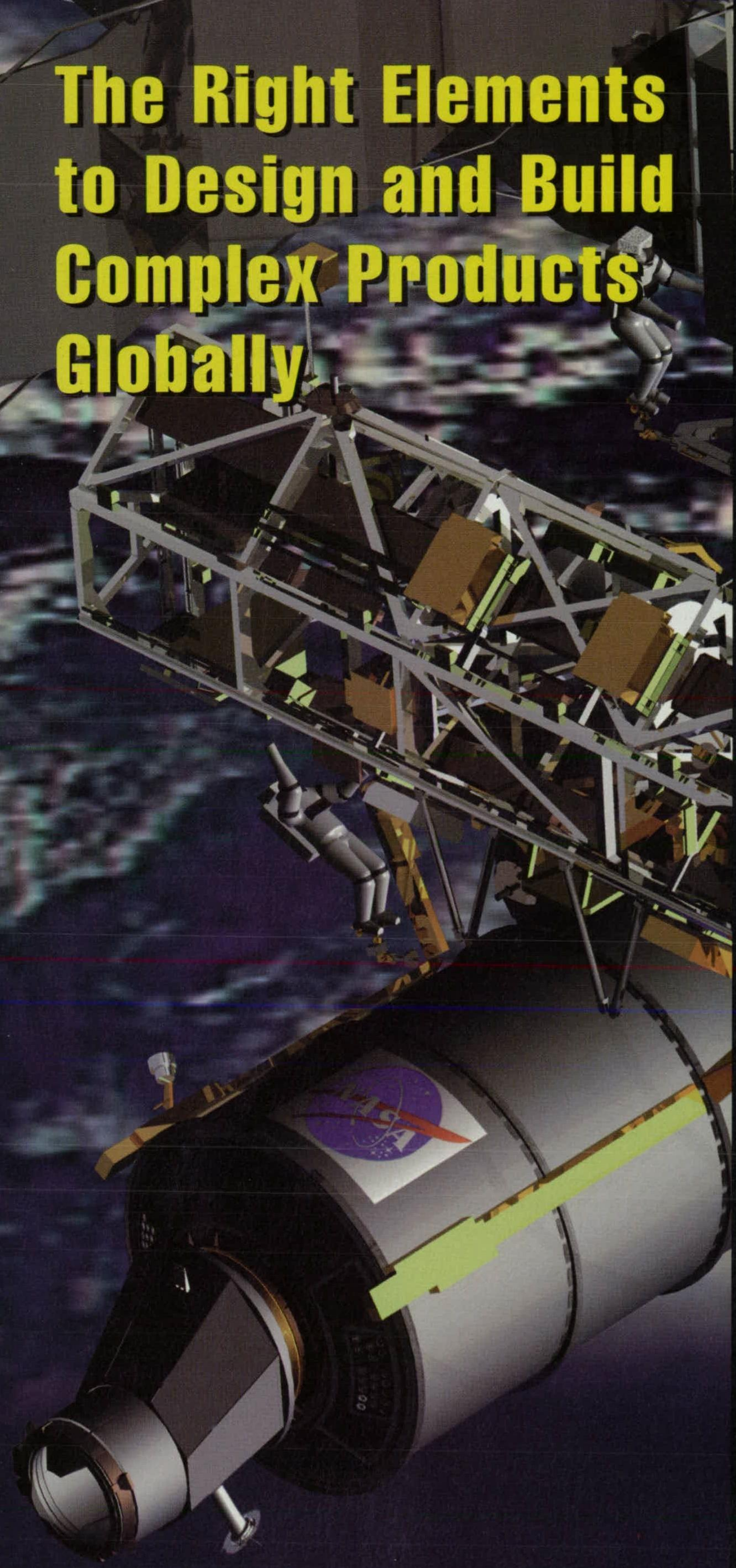
As this issue goes to press, Phase One is coming to a close and Phase Two is on hold. On June 8, NASA's Space Shuttle Discovery retrieved Andrew Thomas, the final U.S. astronaut to serve aboard Mir. Not long after Thomas returned to Earth, Russia was to have launched the first ISS component: the Control Module. The second ISS component was scheduled for launch this month. But construction delays in the Russian-provided Service Module, scheduled for the third ISS launch, have compromised these deadlines. On May 31, representatives of the ISS nations agreed to reschedule the initial ISS launch for November 1998 and to revise target dates for the remaining 43 assembly flights. So far, completion of ISS is running only a month later than the original plan, with the final assembly launch now targeted for January 2004.

By the time Phase Three is complete, the entire ISS will have a span of 356 x 290 feet and will weigh 470 tons. It will operate at an average altitude of 220 miles, supporting up to seven crew members in an Earth-like atmosphere.

Construction of the ISS will be the most complex activity ever conducted in orbit, posing enormous technological and logistic challenges. The entire station will be assembled "on the fly" without the advantages of ground assembly and checkout. During complex extravehicular activities (EVAs), astronauts and cosmonauts will join the separate components into a single, orbiting laboratory with crew quarters, solar arrays, a rescue vehicle, and life-support systems.

NASA estimates that the ISS assembly will cost $17.4 billion, and station operations from 2003 to 2012 are expected to cost another $13 billion. But NASA and the other participants have great hopes that the benefits of ISS will far exceed these costs. The project's mission is to create a space-based science institute capable of supporting long-term research in materials and life sciences areas in a nearly gravity-free environment; to conduct medical research in space; and to accelerate breakthroughs in technology and engineering that will have immediate, practical applications for life on Earth. Testing of life-support systems and other technologies aboard the ISS may also serve as "rehearsals" for future lunar and Mars habitation — NASA has tentatively marked the launch of a human expedition to Mars for 2014.

In a recent visit to NASA's Johnson Space Center in Houston, President Clinton expressed his hopes for ISS: "Seven Americans have lived aboard the Russian Space Station Mir. The last six for 25 consecutive months, working with Russia and 14 other nations. Soon the International Space Station will be launched — the size of a football field — so large it will actually be visible to the naked eye here on Earth. Yes, it was a fight for a while and there were those who thought we should abandon it, but we did not, and 10 or 20 years from now, people will wonder why we ever even considered (abandoning it) because we will all, before long, be thanking our lucky stars that we had the vision to work with people from around the world to set up the International Space Station. From it we will explore vast new frontiers, chart unexplored seas, reach a little deeper into the vast final frontier."



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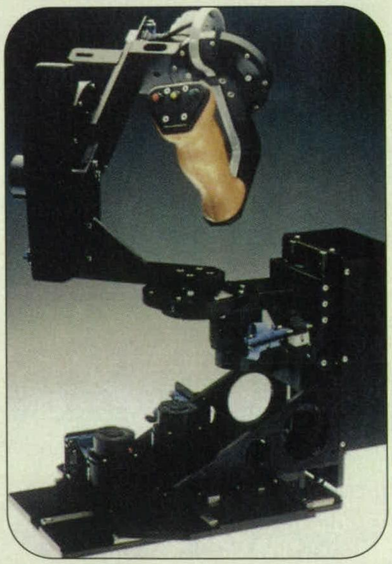
Putting It All Together

The International Space Station (ISS) is taking shape in factories and laboratories in 16 nations around the world. The U.S. alone has a development budget of $17.4 billion; partner nations collectively will add more than $10 billion to the U.S. contribution, the majority of which comes from a $7 billion contract with the Boeing Corp., NASA's integrated prime contractor for ISS. Commercially available products have been — and continue to be — used in the design and manufacture of ISS components and systems. Some of the companies supplying those products are profiled here.

Robotic Handcontroller

The PER-Force™ (Programmable Environment Reality through Force) robotic force-reflecting handcontroller from Cybernet Systems Corp. provides a sense of touch or "feel" for operators of robots and other manipulated objects, enhancing the efficiency of robotic operations that require manipulation and control of objects in multi-dimensional space. The handcontroller originally was designed for use on the Space Station, and was developed through a Small Business Innovation Research (SBIR) contract from NASA's Johnson Space Center.

The backdriveable robot moves in six degrees of freedom: three linear positions (x, y, or z), and three attitudes (roll, pitch, and yaw). An operator uses the motorized handle to precisely position robots or graphically displayed objects to a given location and tool angle. The "feeling" of the objects is achieved through a host computer or robotic control system that reads the handcontroller's joint position, velocity, and force through interface ports. A "force feedback" is generated on each axis, using six small brushless DC servo motors.



The handcontroller was designed for Space Station areas where visibility is limited, or in areas with obstructions or low light.

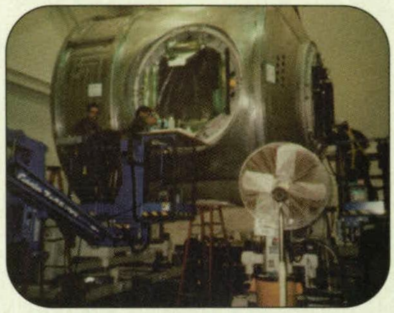
Cybernet Systems Corp., 1919 Green Rd., Suite B 101, Ann Arbor, MI 48105; Tel: 313-668-2567.

Brush Plating Components

Over a period of about one year, more than 300 areas on various partially assembled components of the International Space Station were electroplated in-place at Marshall Space Flight Center using a portable plating process called Brush Plating from SIFCO Selective Plating. The process has been used since 1959 to apply engineered deposits and coatings onto localized areas of components used in a broad range of industries, including aircraft and aerospace.

The nature of the Space Station job lent itself to brush plating. A precise thickness of a deposit was needed on a localized area of a very large part. Assuming that a suitable tank was available, handling a component the size of one of the modules of the Space Station would be no easy task. The complexity of the masking involved would be too time-consuming, and the risk of catastrophic damage that could result from faulty masking would be high. Brush plating allowed the process to be brought to the part, so that with minimal masking to isolate the area to be plated and to control the runoff of solution, a high-quality controlled-thickness deposit could be applied to a localized area.

Plating began in August 1995. SIFCO was responsible for plating on both structural test articles and flight articles that included the STA Node, the STA Common Module, Node 1, the Lab, and an airlock. The plated areas typically were hull penetrations that accommodate electrical connectors and feed through for various fluid or gas lines. Ventilation ducting such as d-holes, utility collars, and IMV flanges, as well as grounding strap contacts, were brush plated. Many of the hull penetrations such as the IMV ports had complex geometries with multiple areas that required precise, uniform thicknesses of nickel plating on both sides of the skin.



SIFCO Selective Plating, 5708 Schaaf Rd., Cleveland, OH 44131; Tel: 216-524-0099; Fax: 216-524-6331; www.brushplating.com

Space Vision System

Space provides few visual cues to gauge depth, distance, or speed, and light levels range from blinding sunlight to pitch black. Under these conditions, astronauts must still be able to perform delicate operations such as launching satellites or docking the Space Shuttle. The Advanced Space Vision System (ASVS) from Neptec Design Group turns the shuttle cabin into a room with a view, providing astronauts with exact location, orientation, and motion information through a computer-generated view of the payload and any important reference points.

NASA has made the ASVS one of the baseline components for on-orbit assembly of the Space Station. The ASVS shows mission specialists what an object looks like from an ideal location. Used with the Canadarm, the system serves as a precision guidance system. The system has been used in a number

of shuttle missions that began in 1992.

Once the shuttle is in orbit, ASVS uses one or more of the shuttle's external cameras as sensors to monitor a pattern of target dots on the payload. The targets are acquired, or locked-onto, by the system. The calculated position, orientation, and rate data is synthesized into a real-time, computer-generated display. Video signals from the exterior-mounted shuttle cameras are passed to the ASVS, where it determines the position and orientation information of the payload. ASVS then feeds video signals directly to the shuttle's video system. Displays appear on the shuttle's monitors.

Neptec Design Group, 175 Terence Matthews Crescent, Kanata, Ontario, Canada K2M 1WB; Tel: 613-591-0931.

Testing and Validating Subsystems

Two System 500 Model 55-based test and integration systems from L-3 Communications Telemetry & Instrumentation are being used by subsystem integrators of the Space Station as part of a $1.9 million contract with Boeing. The test systems each consist of three commercial-off-the-shelf (COTS) Model 550 chassis, which are used to simultaneously monitor, correlate, and record up to 44 MIL-STD-1553 buses in real time. The processing capability is vital to establish baselines for validation and integration of the Space Station's complex subsystems.

Data from the test stations is distributed to multiple engineering groups throughout the Space Station complex in Huntsville, AL. The groups monitor real-time data as tests are conducted, and analyze recorded data to verify subsystem performance. Test data is rerouted over the facility's high-speed 100BaseT network so these groups simultaneously can access whatever live or recorded data they require.

Beyond the standard bus testing capabilities, the test stations support a variety of communications protocols unique to the Space Station. Specialized protocols such as boxcar, packet, and CCSDS protocols are required to accommodate the complex data bus architecture used by the Space Station.

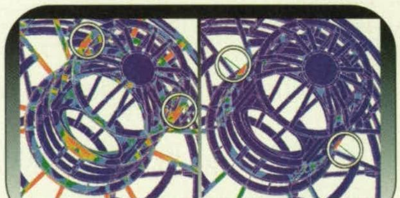
Customers building and integrating subsystems for scientific experiments on the Space Station also can use the test stations, since those subsystems need to be compatible with the station's existing subsystems, and must be similarly tested and validated.

L-3 Communications Telemetry & Instrumentation, 15378 Avenue of Science, San Diego, CA 92128-3407; Tel: 619-674-5100; Fax: 619-674-5145.

FEA Software for Component Design

Bergaila Engineering Services of Houston, TX, is designing components for the Space Station and its testing module using Superdraw III finite element analysis (FEA) software from Algor.

In January 1999, a crew of three is scheduled to begin living aboard the station. To train astronauts for maneuvers in space, a module is being constructed for the Neutral Buoyancy Laboratory in Clear Lake, TX. The lab is a large pool that measures 102 feet wide, by 202 feet long, by 40 feet deep. Modules are submerged in the pool, and astronauts practice maneuvers that will take place outside the Space Station. The components must be strong enough to withstand the stress of support systems in and out of the pool, as well as the lifting system and buoyancy.



Initial Airlock Lift Configuration — Final Airlock Lift Configuration

Bergaila engineers built a 37,000-plate/shell element model of the 7-A airlock, from which trainees emerge into the water. The model was based on the Space Station design using the FEA software. Based on the analysis results, it was determined that the lift configuration used to move the module in and out of the pool should be changed to lower stress levels and deflection.

Bergaila also worked with Superdraw III to design and analyze a potential flight hardware component for the Space Station — the aluminum Re-supply Storage Platform (RSP). The platform had to weigh less than 150 pounds and support up to 500 pounds of equipment.

A combined beam and plate/shell model of the RSP was designed with

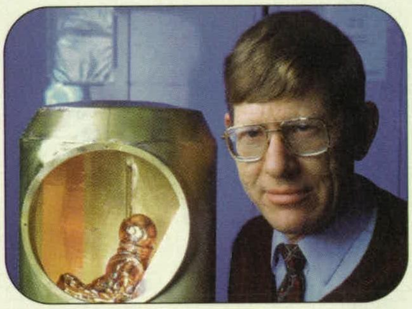
the software. For each design, a series of 20 linear stress and vibration analyses were conducted. Dozens of design variations were analyzed to determine the best three or four designs. Linear dynamic response analyses on other existing flight hardware components also were performed. The results of those analyses helped engineers determine the net effects of launch- and crew-induced vibrations.

Algor, 150 Beta Drive, Pittsburgh, PA 15238-2932; Tel: 412-967-2700; Fax: 412-967-2781; www.algor.com

Antenna Provides Astronaut Communication

A two-foot-long loop design antenna, called an Orlan antenna, was developed by the Georgia Tech Research Institute (GTRI) for use on the Space Station. It is being developed for the crew lock, a cramped cylindrical air lock that can hold two space-suited astronauts. Because of its positioning, the sensitive antenna must survive bashing by space packs, huge temperature swings, and serve as a hand- and foot-hold for astronauts in space.

Researchers at GTRI's Sensors and Electromagnetic Applications Laboratory have been working with The Boeing Co. on the project since last year. The greatest technical hurdle involved the antenna's location within the crew lock. Since the antenna needs to go inside a metal container and provide a radio-frequency field for communications, ordinary techniques don't apply, because a radiation pattern is meaningless inside a resonant cavity, according to Victor Tripp, principal research engineer with GTRI.



Researcher Victor Tripp with a scale model crew lock and astronaut. (Photo by Stanley Leary, courtesy of Georgia Institute of Technology)

The antenna's job is to provide communications for Space Station astronauts using Russian-designed spacesuits, which employ the same frequency used for many years aboard Mir. The frequency is four times lower than that used by US spacesuits.

Dependable operation of the crew-lock antenna is crucial. While astronauts wait within the crew lock sealed into spacesuits, the antenna carries verbal communication between astronauts and crew, and transmits vital signs and other data for monitoring each astronaut's physical condition.

Georgia Tech Research Institute (GTRI), 430 Tenth St., NW, Ste. N-112, Atlanta, GA 30318; Tel: 404-894-3444; Fax: 404-894-6983; www.gtri.gatech.edu

Controlling Onboard Displays

NASA's Automation, Robotics, and Simulation Division (AR&SD) chose Sammi graphical software from Kinesix Corp. for real-time command and control of the Space Station's onboard systems, robotics, and NASA-provided payload displays. Sammi is a client/server and web-development framework that allows creation, testing, and maintenance of graphical applications on Windows NT, UNIX, and Java platforms.

Sammi's base use is within the Mission Control Center. The operators and controllers — including the Guidance Officer, Flight Dynamics Officer, Navigation, Environmental Systems, and Flight Surgeon — will use Sammi as an interface to their systems. The software also will be used to help simulate control of the Remote Manipulator System (RMS) robotic arm on the station.

Sammi's web-enabling technology will allow NASA engineers to view dynamic graphical representations of remote, on-line data from an unlimited umber of measurement points. Once a display is created, the software enables multiple concurrent connections to systems such as command and control interfaces, distributed and remote control, network monitoring, and energy management.

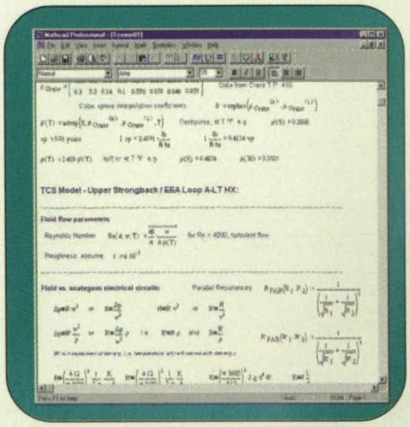
Kinesix Corporation, 7700 San Felipe, Suite 200, Houston, TX 77063; Tel: 713-953-8300; Fax: 713-953-8306; www.kinesix.com

Electrical Power System Design

To monitor thousands of different components for the Space Station development, NASA implemented an Independent Assessment Team (IAT) to oversee the quality of the different projects across the country. The IAT, chartered by NASA Headquarters' Office of Safety and Mission Assurance, provides independent evaluations of technical and other programmatic issues that could jeopardize the Space Station mission.

At the Rocketdyne Division of Boeing North American in Canoga Park, CA, the IAT monitors the design and fabrication of the station's electrical power system. A significant part of the IAT's evaluation of Rocketdyne's work involved the use of Mathcad Professional technical calculation data analysis software from MathSoft.

Jim Swavely, a member of the IAT, used Mathcad in his analytical work on the station's electrical power system, which operates like the avionics power distribution system of an airplane. Mathcad enabled Swavely to provide simulations of electrical hardware and software systems, allowing him to conduct performance analysis at the system level. Simulations also were created for specific components such as hydraulics for the ammonia pump used in the thermal control systems.



In one analysis, Mathcad was used to evaluate a specific software component — a complicated data filter that examines voltages and currents data. The data software filter is designed to validate real-time airborne flight data by flagging each piece of data and assigning it either a "0" for invalid data, or a "1" for valid data. The information was used for voltages and currents in the overall electrical power system performance. The filter's software code was translated into Mathcad, where Swavely was able to simulate different scenarios and test filter performance.

MathSoft, 101 Main St., Cambridge, MA 02142-1521; Tel: 617-577-1017; Fax: 617-577-8829; www.mathsoft.com

Analysis Modeling Software

The Boeing Company has implemented FEMAP from Enterprise Software Products as its primary analysis modeling and visualization software on the International Space Station. As a result, all major Integrated Project Teams on the Space Station are now using FEMAP as their primary tool for modeling and visualizing their design analysis studies. The software is integrated with existing NASTRAN and ABAQUS solvers to perform stress and dynamics analyses.

FEMAP software for computer aided engineering (CAE) simulates product and process performance, reducing or eliminating physical prototypes. FEMAP has extensive support for leading finite element solvers. Initially skeptical that a Windows-based system could provide the comprehensive capabilities required on a project the size of the station, Boeing evaluated FEMAP during 1996. As a result, Boeing proceeded with an aggressive implementation of FEMAP in 1997. Today, all mechanical analyses for the ISS are modeled, visually interpreted, and documented using FEMAP, which is integrated with Boeing's Windows 95 and Office 95 Information Systems environment.

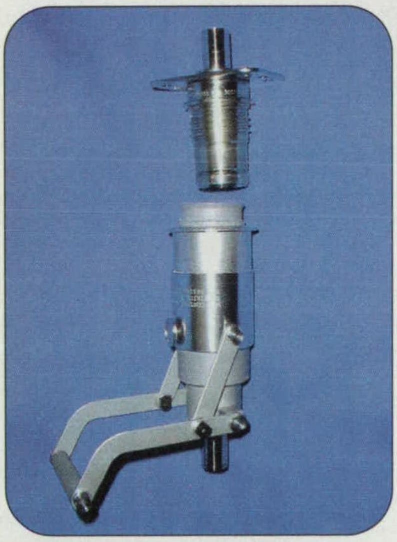
Enterprise Software Products, 411 Eagleview Blvd., Ste. 108, Exton, PA 19341; Tel: 610-458-3660; Fax: 610-458-3665; www.femap.com

Coating for Quick-Disconnect Couplings

The Space Station requires a number of quick-disconnect couplings that provide increased cycle operation life. The couplings' valves must be smooth, hard, and durable to prevent sealing surface damage during transportation or when opening or closing the valves. When operating at temperatures as low as -160°F, damage to the valves can result in unacceptable levels of system fluid leakage, which would contaminate the station's external facilities and/or its internal habitat.

Design engineers at Parker Hannifin Corporation's Symetrics Business Unit chose NEDOX® coating from General Magnaplate to achieve the hardness, durability, and smoothness necessary for optimum performance of their couplings. General Magnaplate coatings had been used on hundreds of parts for various space missions, including the fuel mixing valves for the lunar module on Apollo 13, and the core sample drill used by the astronauts on the Moon.

During the early development phase of the Space Station, a custom-designed version of NEDOX — called SF-2NT — was created by General Magnaplate. The thin film coating permanently dry-lubricated the surface while providing a hardness of up



to Rc68. In cooperation with Boeing Space, McDonnell Douglas Aerospace, and Rocketdyne, the process procedures for component preparation, as well as the NEDOX SF-2NT coating and finishing, were improved.

The Symetrics valve components for the Space Station's quick-disconnect couplings are manufactured from Inconel or stainless steel, and are polished, cleaned, packed, and sent to General Magnaplate's facility in Ventura, CA, where the NEDOX coating is applied.

General Magnaplate, 1331 Rte. 1, Linden, NJ 07036; Tel: 908-862-6200; Fax: 908-862-6110; www.magnaplate.com

Mechanical CAE Products for Component Analysis

A number of companies across the country are using mechanical computer-aided engineering (MCAE) and finite element analysis (FEA) products from MacNeal-Schwendler Corp. (MSC) for Space Station applications. One company that incorporated MSC/NASTRAN finite element analysis software was McDonnell Douglas and McDonnell Douglas Aerospace.

For McDonnell Douglas, an obstacle arose due to the difficulty of correlating each analytical mode shape with the measured data in loads analysis. Dynamic mathematical models used in the launch vehicle verification loads analysis for predicting the flight loads and assessing the structural integrity are required to be test-verified. The test-verified model usually is developed after conducting a modal survey on a structural test article and correlating the measured frequencies and mode shapes with the analytical prediction. However, it is not practical to instrument a test article in all degrees of freedom corresponding to those of the analytical model. Therefore, the problem of each shape developed. A systematic approach utilized MSC/NASTRAN version 67.5 direct matrix algorithm program (DMAP) to minimize the effort for test-analysis model reduction and correlation.

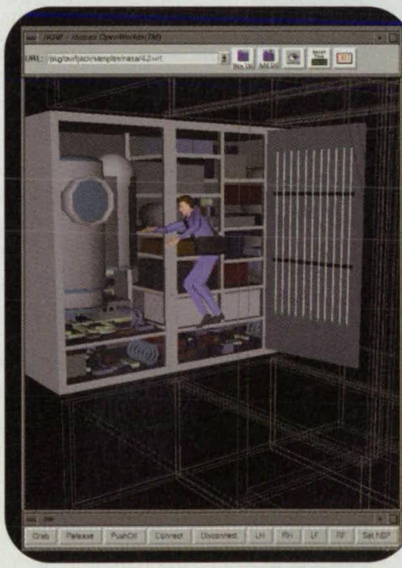
McDonnell Douglas also used MSC/NASTRAN in the Space Station's primary structural elements being assembled and operated in the severe on-orbit thermal environment. The changing environment results in a broad range of structural load conditions defined by spacecraft articulating geometry, orbit inclination, flight alti-

tude and attitude, and the annual solar cycle. Integrated analysis approach was developed using MSC/NASTRAN structural models to compute thermally induced loads and deflection specifications for the station's pre-integrated truss segments.

MacNeal-Schwendler Corporation, 815 Colorado Blvd., Los Angeles, CA 90041-1777; Tel: 213-258-9111; Fax: 213-259-4979; www.macsch.com

Virtual Reality for Astronaut Training

Open Worlds™ virtual reality software was developed by DRaW Computing Associates under a NASA Small Business Innovation Research (SBIR) contract managed by Marshall Space Flight Center in Huntsville, AL. NASA required software that would allow it to create virtual reality simulations to facilitate training future crews for the Space Station. Open Worlds' scripting, hardware, and graphical user interface front end enabled Marshall researchers to create complex virtual reality simulations while designing the station's various elements.



DRaW Computing works closely with the University of Pennsylvania's Center for Human Modeling and Simulation (HMS), the developer — with NASA's Johnson Space Center — of the Jack™ human simulation software that is now available commercially as Transom Jack™ from Transom Technologies.

Human OpenWorlds (HOW), a VRML add-on module for the Transom Jack human simulation system, provides full VRML simulation editing capabilities for expanded behavior control in Jack, as well as VRML importing and animation capabilities. The HOW with Jack interface was tested for the Space Station application. More HOW nodes were added, both general-purpose utility nodes and Jack-specific nodes.

Using the combined software, the virtual environment of the Space Station was populated with biomechanically accurate human figures that respond to changes in balance, field of vision, and flexibility exactly the way a real astronaut would. NASA then was able to observe the astronauts' behavior in limited spaces, designing Space Station modules accordingly.

DRaW Computing Associates, 3508 Market St., Ste. 203, Philadelphia, PA 19104; Tel: 205-382-0390; www.drawcomp.com

Where Science Goes From Here

The International Space Station is designed to be a testbed for the technologies of the future, serving as an orbiting laboratory for research on new, high-tech industrial products and materials, as well as potentially remarkable breakthroughs in medical technology.

The International Space Station will provide the opportunity for experimental research in the near absence of gravity — also called microgravity — which could produce new insights into human health, disease prevention and treatment, industrial processes, heating and cooling systems, waste management systems, robotics, and long-duration space flight. When completed, the ISS will house six laboratories: two from the U.S., one from the European Space Agency, one Japanese experiment module, and two Russian research modules. The station labs will house a variety of experiments in 37 refrigerator-sized racks. NASA will have 97% of the research space in the U.S. lab.

Simply, microgravity is a condition in which the effects of gravity are greatly reduced. The microgravity environment associated with the Space Station is the result of being in orbit, which is a state of continuous freefall around the Earth. Microgravity provides a unique environment for scientists to observe and explore phenomena that normally are masked by the effects of Earth's gravity.

The Space Station will house research on such things as the growth of protein crystals, which could greatly enhance drug design; disease prevention and treatment; and the study of materials that could not exist and processes that could not take place on Earth because of the effects of gravity. These include polymers used for everything from contact lenses and paint, to semiconductors and high-temperature superconductors.

Microgravity Research Areas

The ISS will house seven dedicated research areas for microgravity experiments: Biotechnology, Combustion Science, Fluid Physics, Fundamental Physics, Materials Science, Advanced Human Life Support, and Human Research.

Biotechnology - Biotechnology is an applied biological science that involves the research, manipulation, and manufacture of biological molecules, tissues, and living organisms. This area is likely to play an important role in our lives in the next century, with its expanding role in health, agriculture, and environmental protection. The biotechnology experiments on ISS will focus on protein crystal growth, mammalian cell and tissue cultures, and fundamental biotechnology.

Humans contain 150,000 proteins that help us maintain life, but understanding the structure of those proteins has eluded scientists. Microgravity will allow researchers to grow protein crystals that are bigger than those that can be grown on Earth. According to NASA, pharmaceutical companies could benefit through the development of drugs that inhibit a specific protein that causes a disease.

Combustion Science - Combustion is a key element of many of our critical technologies, including electric power, home heating, aircraft propulsion, and materials processing. The microgravity combustion experiments on the ISS will study how flames ignite, spread, and extinguish under microgravity.

Fluid Physics - A fluid is any material that flows in response to force, including colloids, gels, foams, granular systems, and even gases. Fluid physicists will use microgravity experiments to understand the physical principles that govern fluids to advance fluid science and technology. A better understanding of how the structure and properties of a solid metal are determined by fluid behavior during its formation can help materials engineers.

Fundamental Physics - Fundamental physics studies the basic laws that govern the physical world on all scales, from microscopic to cosmic. Microgravity experiments in this area can be used to test some fundamental theories of physics, including Einstein's theory of general relativity, and Newton's laws of gravity.

Materials Science - This broad field covers the study of all materials, including the formation, structure, and properties of materials on various scales. The microgravity materials science experiments will study issues in materials solidi-

fication and crystal growth. These areas encompass the roles of sedimentation and hydrostatic pressure in the formation of electronic and photonic materials, metals, alloys, composites, glasses, ceramics, and polymers.

Advanced Human Life Support - An experiment rack devoted to testing concepts that could lead to development of more efficient regenerative life support systems will be included on the ISS. One aim of the tests is to improve recycling systems. In space, an astronaut will require 23 pounds of water each day for food preparation, hygiene, oxygen, and drinking, according to NASA. If astronauts are expected to stay on the ISS for months, or even years, advanced recycling systems must be designed to recycle water — including body fluids — into drinking water.

Human Research - Studies on how the human body reacts to extended stays in space will be conducted. Based on studies already conducted aboard Mir, NASA has learned that bones lose about 1% of calcium for every 30 days an astronaut is in space, and that muscles atrophy from weightlessness. The human research experiments aboard the ISS will take blood samples, measure muscle strength, and record changes over time.

Benefits on the Horizon

NASA already has used microgravity to develop drugs that reduce heart surgery complications; to design proteins that can mitigate the effects of the flu; and to understand the structure of insulin. Medical equipment and technologies developed for the early space program are still paying off today. The cool suit developed for Apollo astronauts continues to help improve the quality of life for multiple sclerosis patients. A pacemaker that can be programmed from outside the body is the result of NASA-developed instruments that measure bone loss and density without penetrating the skin.

With the ISS, microgravity research potentially could lead to further technological breakthroughs that could not be discovered on Earth, particularly in the medical field. Research equipment developed for the ISS already is paying dividends on the ground. Ovarian tumor samples are being grown in NASA's new cell-culturing bioreactor so that tumors can be studied outside the body, without harming the patient. A similar trial is underway for brain tumors.

The bioreactor on the ISS will grow three-dimensional samples of human tissue that will be far superior to the two-dimensional samples grown on Earth. Developments in tissue growth may lead to space-grown cartilage, bone marrow, heart muscle, skeletal muscle, and liver and kidney cells that could replace damaged human tissues. The bioreactor also will be used to further understand tumors by preparing better models of human colon, prostate, breast, and ovarian tumors.

Microgravity research also will allow new insights into disease prevention and treatment, including heart, lung, and

kidney function; cardiovascular disease; osteoporosis; hormonal disorders; and immune system function. Protein crystals grown on the ISS will be used for research into diabetes, emphysema, and parasitic infections.

Materials research aboard the ISS will include a study of crystallization processes and their importance in electronic materials, which play a major role in the operation of computers, medical instruments, power systems, and communications systems. Semiconductors are a prime example of an electronic material and are a primary target of the microgravity research. Applications include creating crystals for use in lasers, computer chips, solar cells, and x-ray, gamma-ray, and infrared detectors. Knowledge gained from this research include improving glass fibers for use in telecommunications; and creating stronger crystalline ceramics for gas turbines and combustion engines.

Since combustion accounts for 85 percent of the world's energy usage, improved understanding of combustion may help scientists deal with problems such as pollution, global warming, explosions, and atmospheric changes. Research to test improved heating and cooling systems, long-life power converters, chemical storage systems, and air purification systems also may lead to huge savings. For example, a 2% increase in the burner efficiency of heaters would save the U.S. about $8 billion per year, according to NASA.

Fundamental physics research already has led to the development of highly accurate experiment sensors that use superconducting technology. This research spawned the magnetic resonance imaging (MRI) technology commonly used in medical diagnosis. Originally designed for laboratory experiments that used nuclear magnetic resonance (NMR) to study atoms, the sensors were adapted to locate healthy and diseased tissue in the body, in many cases eliminating the need for exploratory surgery.

Technological advances are being integrated on the International Space Station on an unparalleled scale. And at the same time, the expected benefits ISS research may bring to life on Earth are anxiously awaited.

ISS On-Line

Learn more about the Space Station's scientific research, evolving hardware, assembly schedule, and contributions from partner nations via these web sites.

NASA's International Space Station Web Site
http://station.nasa.gov

The official ISS site includes history and overview of the station program, along with assembly updates, information on partner nations and companies, and science and research information. Links include live video-feed images from Kennedy Space Center's ISS processing center, automatically updated every 90 seconds.

"Liftoff to Space Exploration" & NEXUS ISS Site
http://liftoff.msfc.nasa.gov

Marshall Space Flight Center's "Liftoff" home page includes a link to NEXUS International Space Station, which provides details of the science and hardware on the ISS.

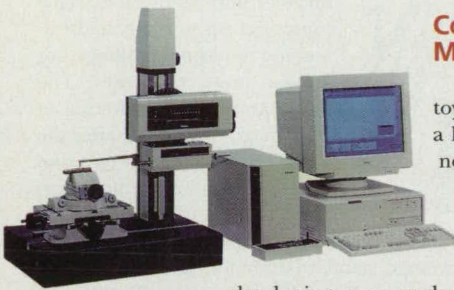
Space Station Biological Research Project
http://pyroeis.arc.nasa.gov/

This site offers detailed information on microgravity-based research in life sciences to be conducted aboard ISS. It includes a diagram and description of the Gravitational Biology Laboratory, which will be part of the ISS research facilities.

Space Today Online: Space Stations
http://www.tui.edu/STO/SpaceStations.html

An entire section of this site is devoted to ISS and other space stations. Links take readers to ISS-related news stories from CNN and other sources. Other links include views of Earth from space and CNN's "virtual tour" of ISS.

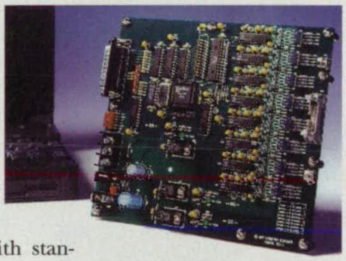
New on the MARKET



Contour/Roughness Measurement

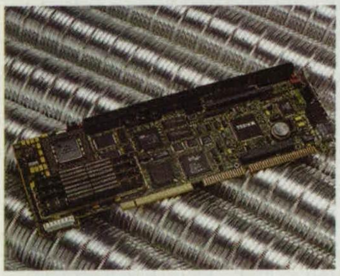
The SV-C524 from Mitutoyo, Aurora, IL, combines a high-level surface roughness tester and a digital contour-measuring unit. Applications include evaluating manufacturing processes, developing new workpiece specifications, and performing sophisticated contour and surface finish analysis. The system features a granite base, precision column, X-axis drive unit, motorized column, control, and computer system. Joystick operation enables manual control of the X/Z drives, measurement start/stop, and stylus up/down motions. In surface texture mode, the system assesses difficult surfaces, short surfaces, and unusual part configurations. FORMPAK-1000 software is resident in the Windows 95 PC-based system. **Circle No. 700**

Data Acquisition System



Symmetric Research, Kirkland, WA, offers the PAR24B data acquisition system, which achieves 22-bit true single sample accuracy at a 20-Hz sampling rate, with a maximum sampling rate of 1 kHz. Its eight individual A/D subsystems eliminate crosstalk and settling problems. Interfaced with standard bi-directional PC parallel ports, the system can be used with laptop or desktop machines when installation of ISA or PCI bus cards is impractical. The parallel port also can be run in EPP mode for fast data transfers. Once converted, incoming digitized data is fully buffered with an on-board FIFO, allowing continuous data acquisition during heavy interrupts or multi-tasking. Software support is supplied, including drivers for DOS, Windows 95, and National Instruments' LabView. **Circle No. 701**

Industrial Single-Board Computer



Teknor Industrial Computers, Boisbriand, Quebec, Canada, has introduced the PCI-934 multimedia industrial single-board computer for OEMs and systems integrators. A single standard AT form factor card, the board is compatible with either ISA or PICMG-compliant PCI-ISA passive backplanes. It accepts all Socket-7 Pentium® processors through 233 MHz with MMX™ technology, with future supports up to 300 MHz. It supports 512 KB L2 cache and 512MB of DRAM. A built-in EIDE disk interface supports four hard drives and 24 MB (or latest density) of CompactFlash™ solid-state disk memory. The system features a floppy-disk controller; serial, parallel, keyboard, and mouse ports; two USB ports; and PC/104-Plus and VIPerVision expansion headers. **Circle No. 702**

Remote Control for Data Acquisition

FreeWave® from SoMat Corp., Champaign, IL, is a wireless modem for long-range data communications that uses spread spectrum frequency hopping with a line-of-sight range of up to 20 miles. The unit provides remote control of data acquisition systems, and features an obstructed range of up to two miles. It incorporates an RS-232 interface; system gain of 140 dB; an aluminum enclosure that weighs only 560 grams; and has an operating temperature range from -40 to +75°C, and operating frequency of 902-928 MHz. It is programmable through any terminal program and operates in either point-to-point or point-to-multipoint mode. **Circle No. 703**

Handheld Digital Thermometers

Omega Engineering, Stamford, CT, offers the HH500 Series handheld thermometers that feature a rugged meter design. The meters accept J/K/RTD inputs in both single and dual inputs, and are C/F switchable with 0.1-degree resolution. HH501A/B models have backlit LCD displays. All models offer data hold — HH502 through HH505 also have min/max/average readings with beeper warning for audible alarming. The thermometers are dust-resistant according to NEMA-4X standards, and are water- and splash-resistant. Also included are a soft carrying case and a shock-resistant rubber boot. **Circle No. 704**

For More Information Circle No. 435

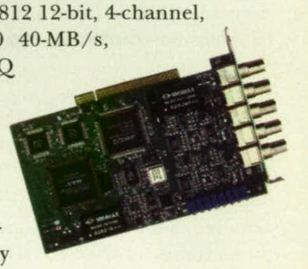
New on the MARKET

Low-Noise Nanovoltmeter

Keithley Instruments, Cleveland, OH, has introduced the Model 2182 nanovoltmeter, with one count in 12,000,000 (over 7 digits) resolution, designed for low-voltage measurements. The unit's "Delta" mode implements the common current-reversal method for canceling thermal emfs (using an external source) at up to 8 Hz, and can average multiple readings for greater noise reduction. The unit features digital filtering of DC voltage readings or after the Delta reading for lower noise levels; two-channel capability; direct reading of J, K, N, T, E, R, S, and B thermocouples; analog outputs for strip chart recording; statistical functions such as average, standard deviation, and minimum or maximum; and measurement ranges of 10mV, 100mV, 1V, 10V, and 100V. **Circle No. 705**

PCI Bus Data Acquisition

The GageDAQ family from Gage Applied Sciences, South Burlington, VT, consists of four PCI bus, multi-channel, mid-range data acquisition cards: the GageDAQ 9812 12-bit, 4-channel, 20 MS/s A/D card; GageDAQ 7300 40-MB/s, 32-bit digital I/O card; GageDAQ 9118 333-kHz, 12-bit, 16-channel A/D card; and GageDAQ 7230 isolated 32-bit digital I/O card. Applications include ultrasound imaging, high-speed memory transfers from other computers, factory automation, and monitoring of proximity switches. **Circle No. 706**



High-Performance Workstation

The Dell Precision™ WorkStation 410 from Dell Computer Corp., Round Rock, TX, enables graphics- and data-intensive Windows NT applications such as CAD, geographic information systems, digital content creation, and software development. The computer is powered by single or dual 350- or 400-MHz Pentium® processors with MMX™ technology, and accommodates up to four Ultra2/Wide 9-GB SCSI hard-disk drives, offering 80-MB/second transfer rates. Other features include RAID technology from Adaptec; up to 1-GB of 100-MHz SDRAM; a new industrial design for easy component access; and six available slots for expansion. **Circle No. 707**

Universal I/O Connector

AMP, Harrisburg, PA, has introduced a universal I/O connector system for multiserial, multiprotocol WAN attachment over a single high-density connector system. The connector can be integrated into hardware such as routers and hubs to provide connectivity to a Data Service Unit/Channel Service Unit (DSU/CSU). The system includes a 72- and 160-position cable plug and printed circuit board connector. The plug is designed with insulation displacement contacts for fast cable termination. Industry-standard 4/40 threads provide positive retention of mated connectors. **Circle No. 710**

Screw Locking & Sealing System

The Precote® screw-locking and thread-sealing system from Nylok Fastener Corp., Macomb, MI, can be used in fastening applications in automotive, electronics, computers, aerospace, and other high-tech industries. The system is a chemical adhesive-based system offered in several grades: Precote 5® for thread-sealing where lower strength and easy removal are required; Precote 30® for repeated exposure to elevated temperatures; Precote 80® for high-strength and temperature resistance to 300°F; and Precote 85® for applications requiring a low coefficient of friction and high strength. **Circle No. 755**

Machine & Drive Couplings

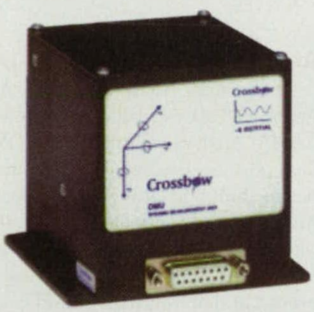
Gerwah zero-backlash couplings from Rimtec Corp., Westmont, IL, are available in safety, metal bellows, and servo insert models with multiple clamping styles. Safety couplings feature a pre-stressed Bellville spring to disengage servomotors within 2-4 ms. They transmit torques from 1 Nm to 1600 Nm. Metal bellows couplings are designed with high torsional stiffness and low inertia; stainless steel couplings are designed to compensate for heat, pressure, and elastic deformation. They can be used to suit bore sizes from 1 mm to 100 mm. **Circle No. 758**

Precision Balances

Setra Systems, Boxborough, MA, offers enhanced versions of the BL and EL precision balances. Features include a collapsible weighing pan that enables the balances to endure 10,000% overloading. The collapsible design provides protection of the balance's ceramic variable capacitance load cell. The pan support mechanism collapses whenever the weight on the pan far exceeds the balance's capacity. The pan then rests on the cast aluminum cover of the balance, supporting any additional weight and preventing further stress on the load cell. Once the weight is removed, the pan support springs back to its original shape. **Circle No. 751**

True Vertical Gyro

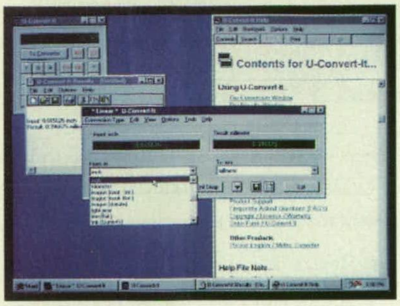
The DMU-VGX high-speed, solid-state, true vertical gyro from Crossbow Technology, San Jose, CA, measures roll and pitch in dynamic environments such as camera stabilization, automotive testing, motion monitoring, and unmanned vehicle orientation sensing. Using silicon micromachined technology and high-speed digital signal processing, the gyro has a mean-time between failure of more than 50,000 hours. Built-in software calculates instantaneous angle from the rate sensors and uses accelerometers to correct for drift and provide a gravity reference. It provides stabilized roll and pitch output with an instantaneous initial erection rate. The unit is packaged in an aluminum housing and measures 3 x 3.375 x 3.25". **Circle No. 712**



New on DISK

Metric Conversion Software

Venmark International, Wellesley, MA, has introduced U-Convert-It™ English/Metric conversion software, a Windows-compatible utility that instantly converts a wide variety of English and metric types, and can paste the results directly into documents, drawings, and spreadsheets. It features thousands of conversion possibilities in categories such as linear, area, density, and volume. To convert numbers in both directions, a "Unit Swap" button automatically switches the two unit types. The program also includes a calculator that transfers directly to the converter's main window. **Circle No. 725**



Data Management for CADKEY

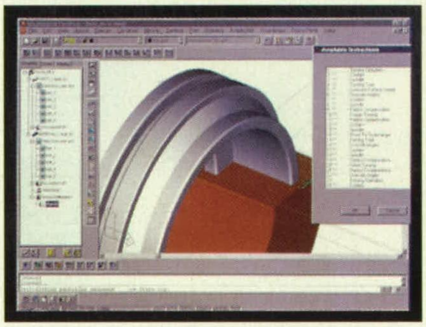
SmartKey™ plug-in PDM/TDM (product data management) software module for CADKEY® 97 users has been introduced by SmarTeam, Peabody, MA. The native Windows-based application is designed to give CADKEY users the tools to create, edit, view, control, and annotate CADKEY engineering drawings and office type documents. Features include a predefined database structure that is ready out-of-the-box; defining queries for locating drawings according to any attribute; and the capability to edit and revise documents from within the CADKEY desktop. **Circle No. 726**

Rapid NC Verification

NC Verify TrueSolid verification software from Sirius Systems Corp., San Jose, CA, is designed primarily for mold and die machining, and can be used for general-purpose 3-axis machining. It supports a SuperTurbo mode, which verifies large manufacturing files at rates averaging between 5,000 and 20,000 points per second, and allows for rapid 3-axis milling. It uses true 3D solid models, enabling users to rotate and zoom into the part. Other features include OpenGL graphics and Rest Machining, which compares the design against the manufactured part to identify flaws. **Circle No. 727**

CAM Programming Software

Pathtrace Systems, Ontario, CA, has announced Version 3.1 of its EdgeCAM programming software, a 32-bit Windows NT- and 95-based CAM system that supports Autodesk's Mechanical Desktop 2.0. EdgeCAM for Mechanical Desktop is designed to reduce programming time through additional automation of programming sequences. Features include new side-cutting grooving cycles that extend the available turning sequences. The software supports 3-1/2-axis and multiplane/rotary milling; surface machining; two, four, C-axis, and Y-axis turning; and two/four-axis wire EDM. **Circle No. 728**



Instrumentation and Control

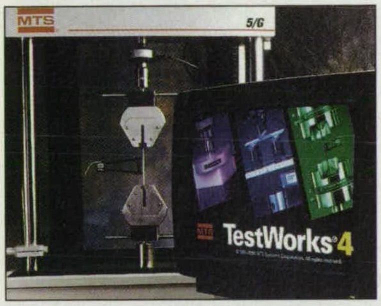
CONTROLpro Version 10.1 Windows-based instrumentation and control software from LTC, Wilmington, MA, features real-time remote access to any portion of the CONTROLpro-based application on the Web; fast Pentium support for both new and old data acquisition and control devices; and an open-architecture design supporting over 1,000 I/O devices from more than 50 manufacturers. CONTROLpro also provides thermocouple measurement via digital filtering and Year 2000 compliance. **Circle No. 731**

Acoustic Analysis in CATIA

Automated Analysis Corp., Ann Arbor, MI, offers COMET/Acoustics® acoustic-analysis software available in Dassault Systèmes' CATIA® Analysis environment. COMET enables product engineers and designers to predict the acoustical performance of their products before building any physical prototypes. Embedded in the CATIA Analysis environment, COMET will generate acoustic-analysis solutions within CATIA's automatic surface and volume meshing. CAT/COMET is designed to offer users a consistent interface with easy-to-use tools to predict and optimize the sound quality of their products. **Circle No. 732**

Mechanical Testing Software

TestWorks 4 mechanical testing software from MTS Systems Corp., Eden Prairie, MN, features a redesigned interface that simplifies test set-up, execution, and monitoring. It runs on Windows NT/95 and is optimized with Pentium™ processors. Other features include a touchscreen option; test sequencing flexibility; virtual manual control panel; and enhanced data acquisition. Interactive graphics include moveable markers and text, construction lines, and selectable region zoom. The software runs on all MTS electromechanical test systems and provides compatibility on virtually any local area network running on Windows NT/95.



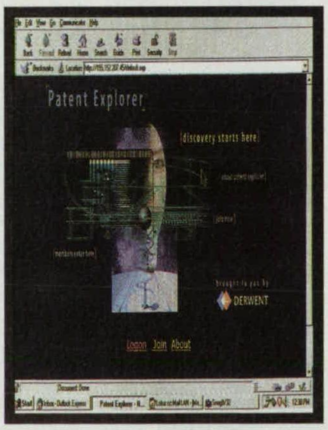
Circle No. 729

PCB Design Suite

Zuken-Redac, Santa Clara, CA, has released CADSTAR MAGNUM 32-bit, Windows-based PCB design suite with unlimited, multilayer autorouting. This means that up to 255 electrical layers can be constructed. Highlights include a Report Generator capable of producing detailed reports for integration into the user's working environment. OLE automation server functionality allows access to the Microsoft standard programmer's interface and built-in function calls to CADSTAR's design database. Testpoint generation is provided in fully automatic and manual capabilities. Split and partial planes can be created in CADSTAR MAGNUM using a dialog-driven interface to control the plane entities. Many alien formats can be imported, allowing migration or integration of different vendors' tools.
Circle No. 733

Global Patent Database

Derwent Information, Alexandria, VA, has introduced Patent Explorer™, an Internet-based service that brings patent information to the desktops of engineers and others in need of competitive intelligence or information for mission-critical R&D. Patent Explorer allows users to zero in on needed information by keyword, patent number, class, or assignee name. Users can then add up to 40 additional criteria to customize searching across the full text of the patent document. Searches can be set up for automatic weekly, monthly, or quarterly execution. Patent Explorer supports Microsoft Internet Explorer 3.0 and above, as well as Netscape Navigator 2.0 and above, using Windows, Macintosh, or UNIX.



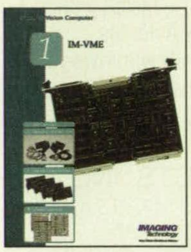
Circle No. 730

New LITERATURE

Sensor Design Guide

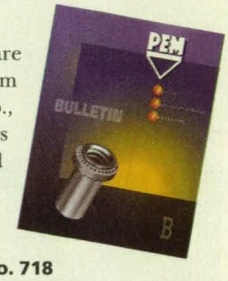
A 200-page design guide features Schaevitz™ Sensors from Lucas Control Systems, Hampton, VA. The guide includes Linear Variable Differential Transformers (LVDTs), position transmitters, dimensional gage heads, magnetostrictive linear displacement transducers, instrumentation, and pressure sensing technologies. Also covered are rotary transformers and transducers, tilt sensors, fluid level sensors, and inclinometers. **Circle No. 720**

High-Speed Vision Processor



Imaging Technology, Bedford, MA, has released a 12-page brochure describing the IM-VME modular pipeline vision processor for real-time image processing and analysis. The VMEbus-based processors are designed for high-speed inspection and machine guidance, image analysis, and complex research projects. Driven by a 40-MHz pipeline architecture, the processor is available with plug-on modules. **Circle No. 717**

Self-Clinching Blind Fasteners



PEM® self-clinching blind fasteners are described in a four-page product bulletin from Penn Engineering & Manufacturing Corp., Danboro, PA. The fasteners provide barriers that protect threads from foreign matter, and protect circuits from intrusion of extra-long screws. The steel and stainless steel fasteners are available in thread sizes from #4-40 through 1/4-20 and M3 through M6. **Circle No. 718**

High-Voltage Digital Drives

A 16-page brochure from Indramat Div., Mannesmann Rexroth Corp., Hoffman Estates, IL, describes the DIAX04 family of intelligent modular drives, which are part of the SYSTEM200 modular control concept. Available as one- and two-axis modular drives, the DIAX04 are designed for applications such as high-speed machining and sheet metal machining. **Circle No. 716**

PCI Data Acquisition

United Electronic Industries, Watertown, MA, offers a 1998 catalog that describes PowerDAQ® PCI data acquisition boards. The boards feature an on-board Motorola DSP and include multi-threaded software support for Windows 95 and Windows NT. A range of cables and accessories also is included. **Circle No. 721**

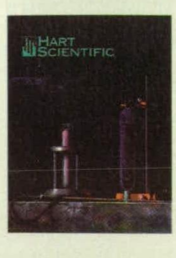
Level/Flow Sensors

The 1998-99 Engineering Guide to Level and Flow Sensors is available from Scientific Technologies, Fremont, CA. The guide describes more than 50 sensor models, including level and flow sensing products for point level detection for solids, liquids, solids/liquids; continuous level detection of solids/liquids; and flow switches for solids, liquids, and gases. **Circle No. 722**

Stepper/Servo Motor Brakes

Electroid, Div. of Valcor Engineering, Springfield, NJ, offers a four-page brochure describing SSB Series front-end stepper/servo motor brakes. The brakes feature a permanent magnet brake design with a torsionally rigid coupling that accepts misalignment. Catalog SSB-1 also describes special configurations available. **Circle No. 715**

Temperature Calibration



Hart Scientific, American Fork, UT, has released its 1998 temperature calibration catalog. The 148-page catalog includes equipment and instruments for the calibration of RTDs, thermocouples, thermistors, and other temperature sensors. The four major product groups covered are primary standards, thermometers, calibration baths, and dry-block calibrators. **Circle No. 723**

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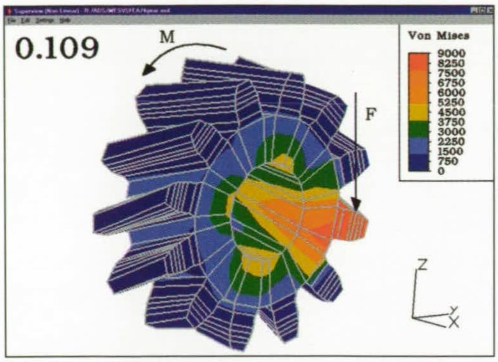
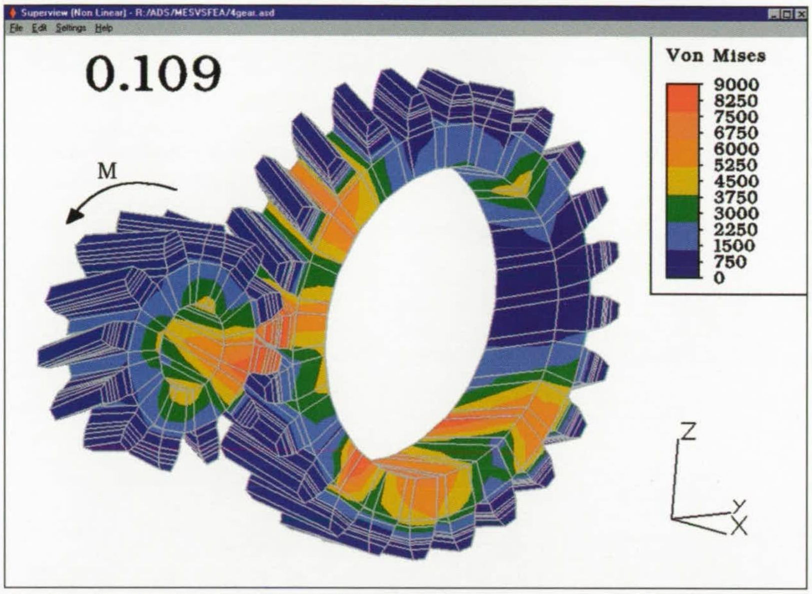
FEA: Old vs. New



In Linear Static Stress Analysis, the forces must sum to zero. The effect of the second gear is simulated by an assumed force or pressure at a single instant in time.



In Algor's Mechanical Event Simulation, the forces sum to Mass times Acceleration (F=MA). Impact forces are transmitted through actual contact between the teeth during gear acceleration.

Old:

In traditional linear static stress analysis, you begin by building an FEA model. Then you set up boundary conditions to anchor the model in three-dimensional space.

If the boundary conditions fail to stop the model from moving in all six primary directions (three degrees of freedom in translation and three in rotation), the static FEA process cannot work. After setting up the boundary conditions, you then apply the moment (M) or torque, which could be generated by an electric motor, and an assumed force (F) or pressure to simulate the reaction of the second gear. After analysis you will have a stress contour for one point in time.

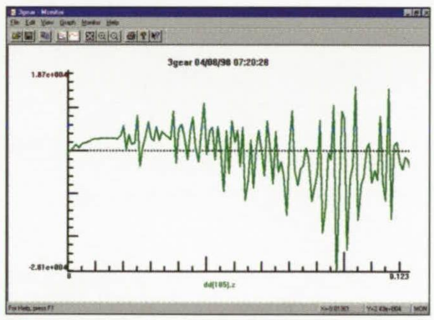
Because the gear teeth are constantly clashing in a random way, the impact forces cannot be known with any precision.

New:

In Algor's Mechanical Event Simulation, you begin the same way by building an FEA model. However, this time you include the second gear.

You place boundary conditions at the pivots. The big gear is free to rotate when forced by the driving gear. Inertia of the entire gear system resists the force of the motor.

When the analysis runs, you will know it's set up properly when you see the gears accelerating and stresses changing as you view the live on-screen "monitor program."



Plot of acceleration vs. time shows high-frequency impacts.

At the end, you see the stresses on all the gear teeth at every point in time.

And, you can make an analysis replay to see the results in real time or slow motion. In addition, you can run a Fast Fourier Transform on the displacement data to highlight any dangers from resonance.

See an analysis replay of this Mechanical Event Simulation at www.algor.com, or contact Algor, Inc. for the latest CD-ROM information/demo pack.

ALGOR®

When the Engineering Has to be Right

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